

# USING THERMOCLINE MANIPULATION TO REMEDIATE MERCURY-CONTAMINATED RESERVOIRS IN SOUTHWESTERN UTAH

 UTAH DIVISION OF  
Wildlife Resources

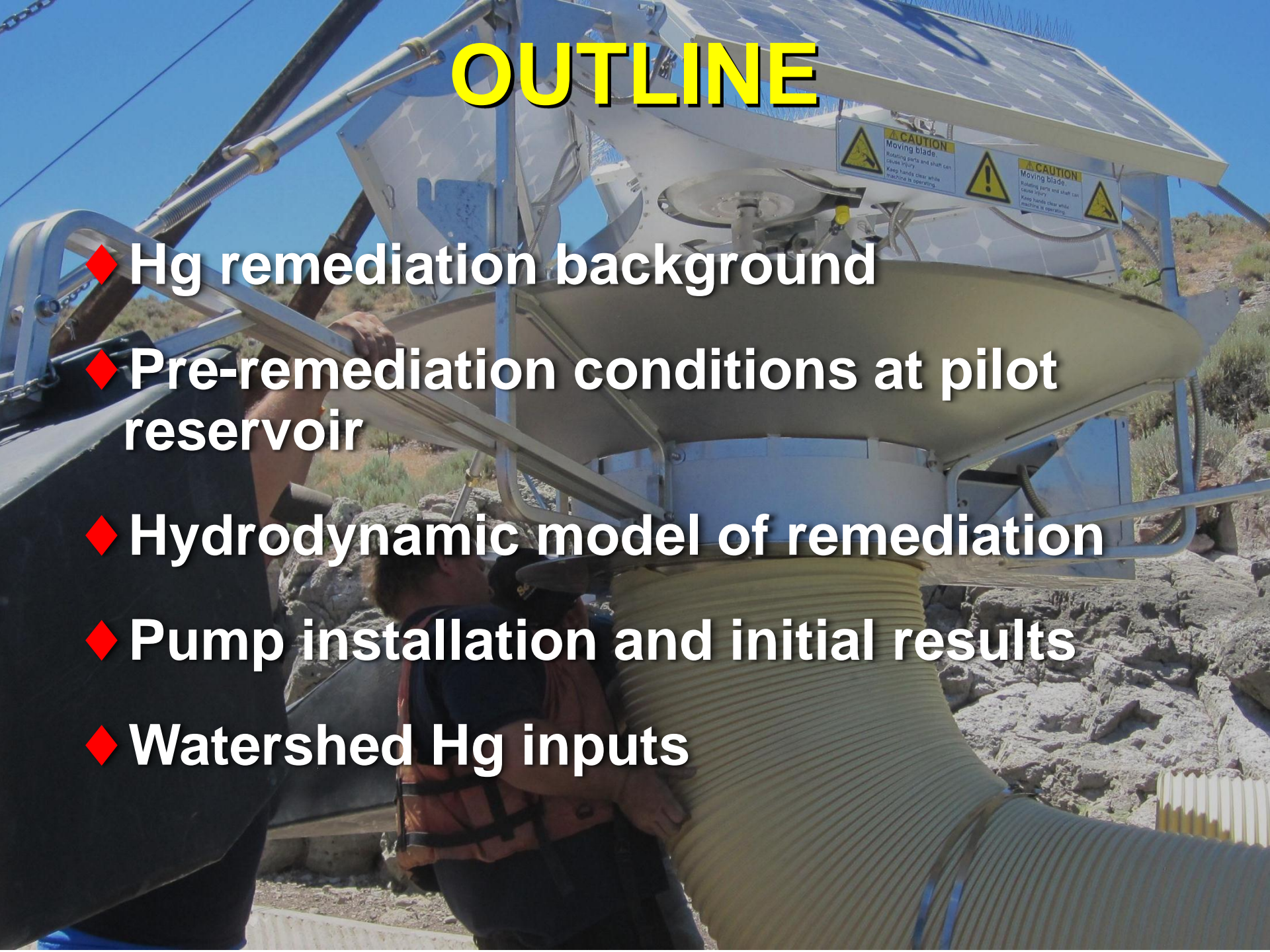


*D. Naftz and C. Angeroth, USGS, Salt Lake City, Utah*  
*R. Jackson, USGS, Urbana, Illinois*  
*J. Whitehead, UDEQ/DWQ, Salt Lake City, Utah*  
*C. Walker, UDNR/DWR, Salt Lake City, Utah*  
*N. Whittier, USGS, Cedar City, Utah*

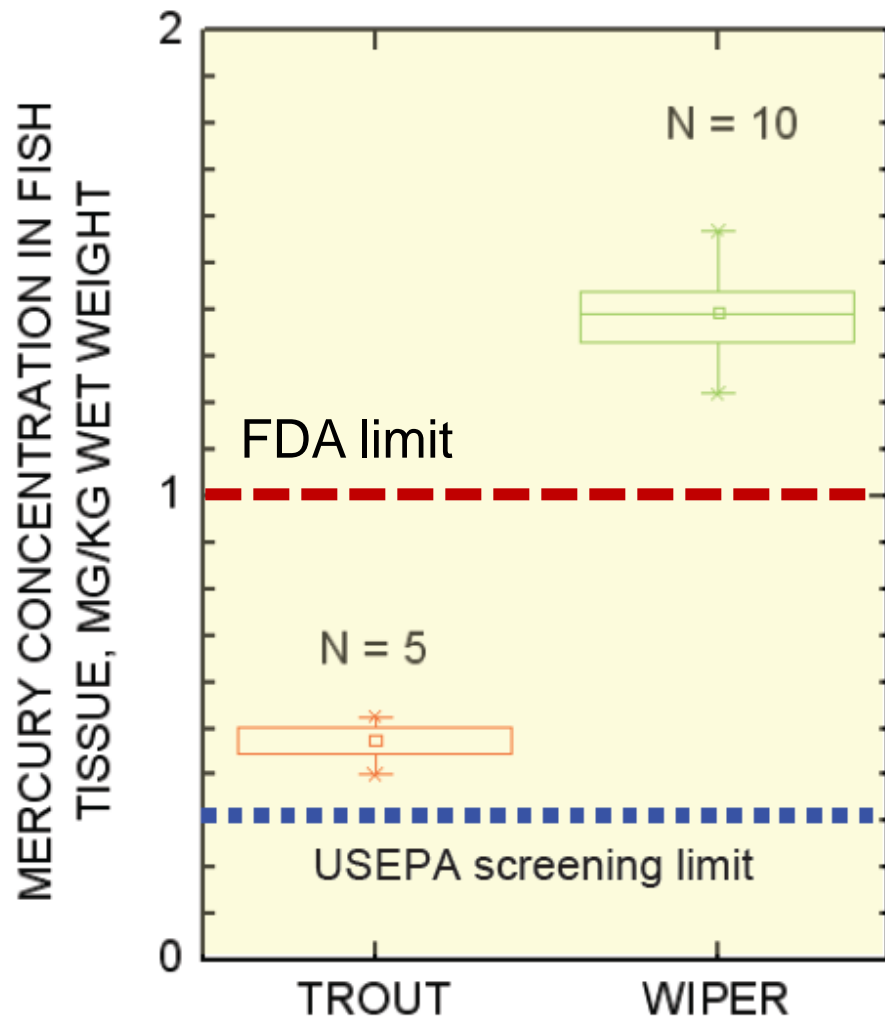


# OUTLINE

- ◆ Hg remediation background
- ◆ Pre-remediation conditions at pilot reservoir
- ◆ Hydrodynamic model of remediation
- ◆ Pump installation and initial results
- ◆ Watershed Hg inputs



# Hg IN UTAH RESERVOIRS



*Data from Utah DWR*

**Utah News.** The Salt Lake Tribune

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## High mercury in fish prompts three new Utah warnings

Environment » 19  
Utah waterways are now listed as having problems with the metal.

BY JUDY FAHYS  
The Salt Lake Tribune

First published Aug 23 2011 11:35AM  
Updated Aug 23, 2011 11:49PM

State health and environmental officials added three new locations Tuesday

## ATTENTION ANGLERS

### FISH CONSUMPTION ADVISORY

High levels of mercury have been found in **Wiper**

**Where:** Newcastle Reservoir

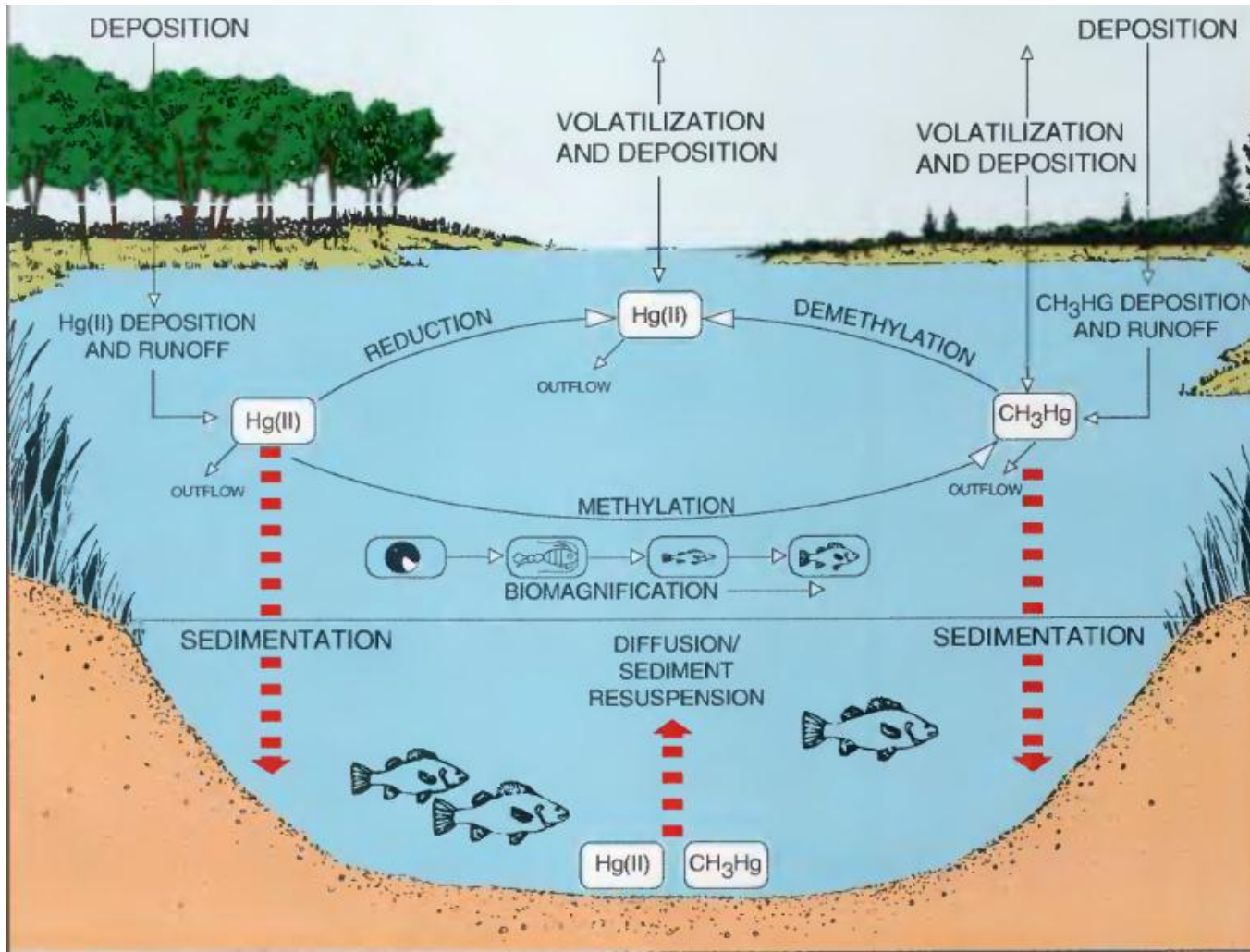
**Recommendations:**

- Utah public health officials recommend that adults **NOT** eat these fish.
- Pregnant women, nursing mothers, and children under 12 are also advised **NOT** to eat these fish.

Hg removal ♦ Pre-pumping ♦ Model results ♦ Remediation ...



Krabbenhoft and Rickert (2005)

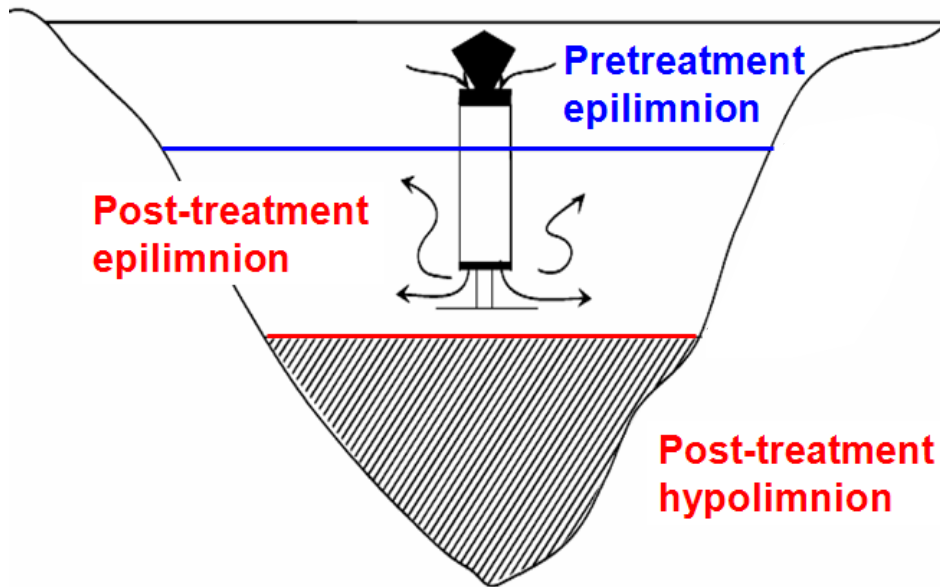


Hg removal ♦ Pre-pumping ♦ Model results ♦ Remediation ...

# Hg REMEDIATION

*Utah regulatory agencies can't do much about controlling atmospheric sources of mercury, but may be able to do something about managing Hg methylation*  
*Rask and others, Biogeochemistry (2010) 101:311–322*

**Does lake thermocline depth affect methyl mercury concentrations in fish?**



- ◆ **Decreased volume of water with high methyl mercury**
- ◆ **Decreased surface area of low oxygen sediment**

# DECREASE IN METHYL Hg

(Rask and others, 2010)

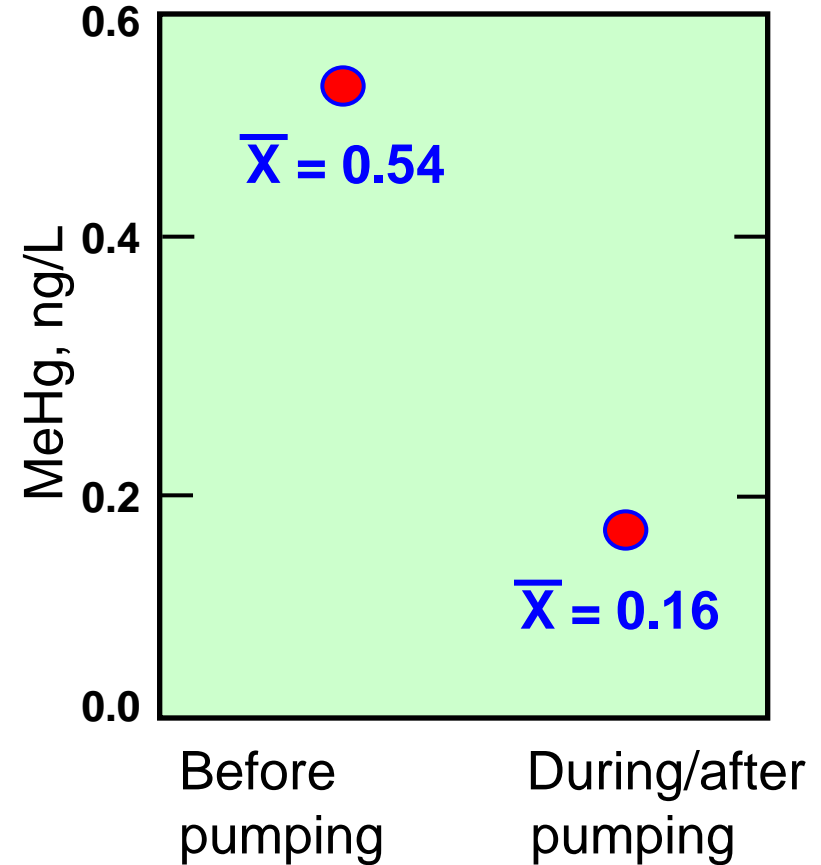
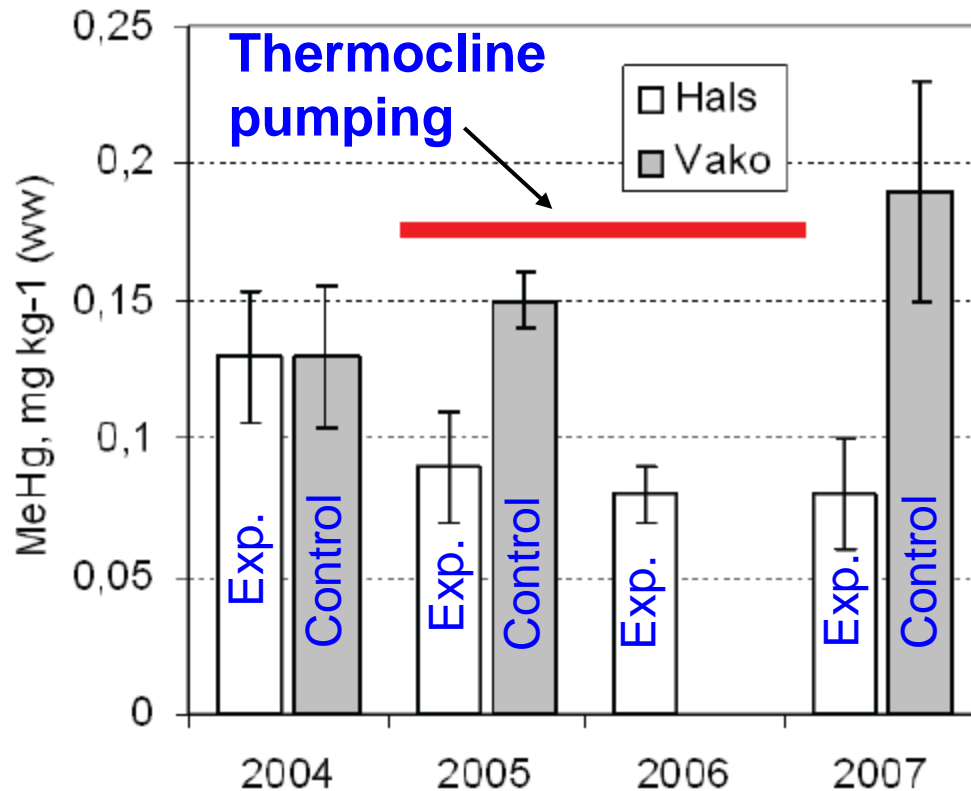
Fish tissue

**FINLAND**

Water

(small perch, 70-80 mm)

(epilimnion)



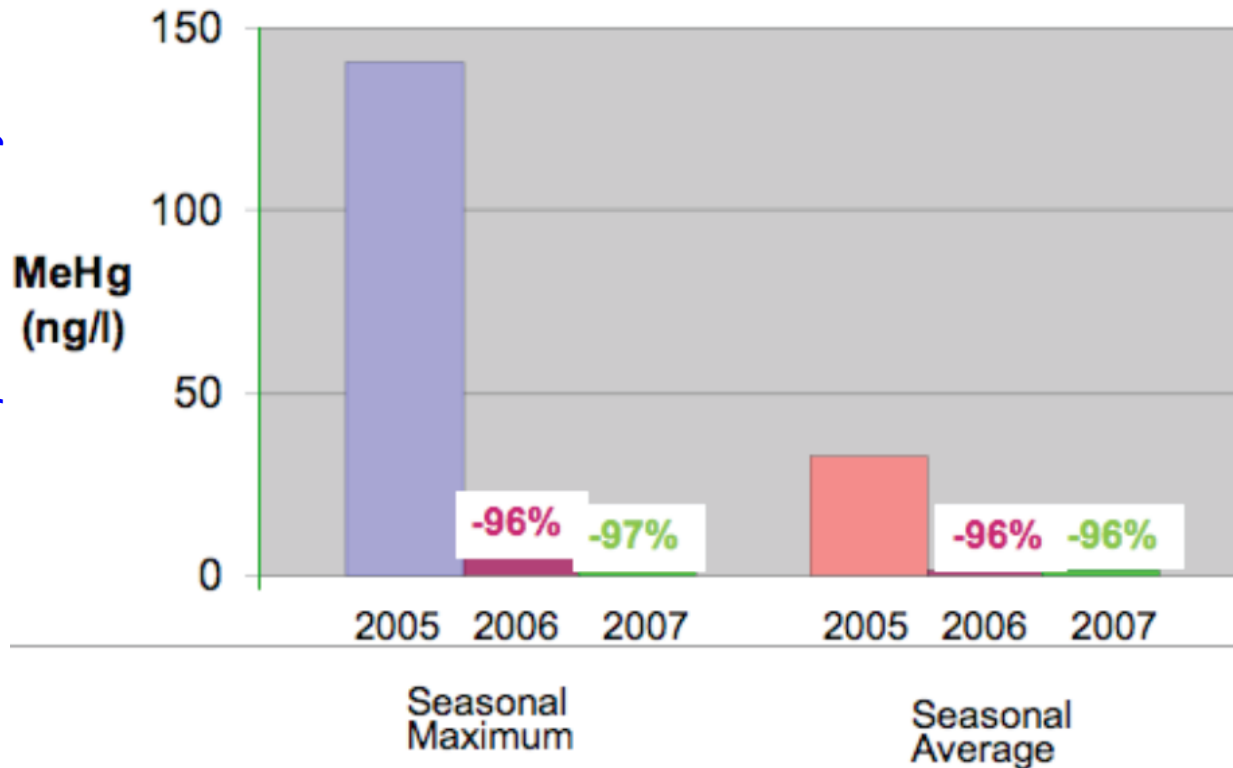


# Hg REMEDIATION

*Almaden Lake, California*

## Site 1 Mid-Depth (7m)

Seasonal Maximum and Average Methyl Mercury Concentrations



♦ May 2006—Solar pump installed to facilitate aeration of anoxic bottom water

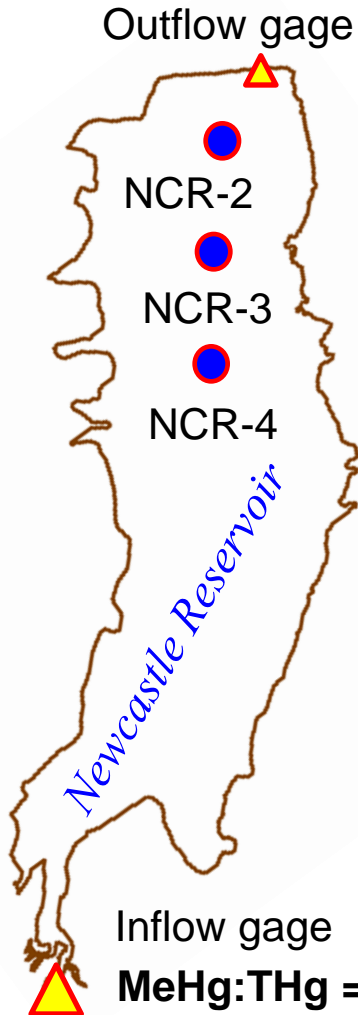
♦ MeHg in water reduced by 96%



*Solar pump on Almaden Lake*

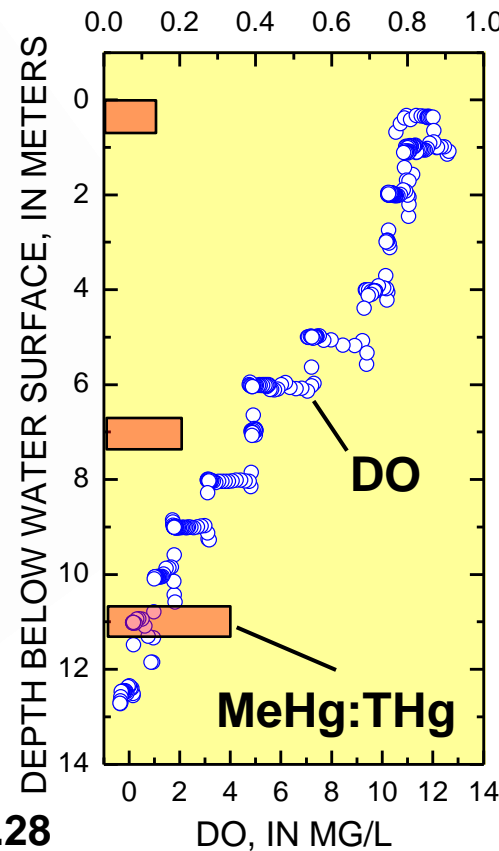
# INCREASE IN METHYL Hg

July 2010



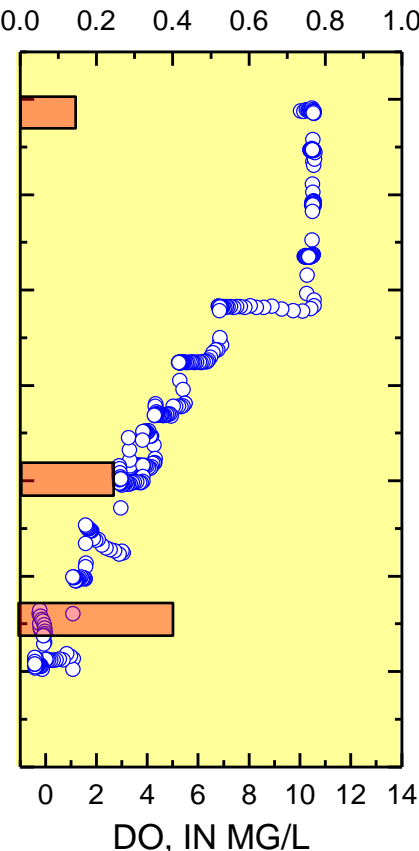
**NCR-2**

MEHg:THg (MASS)



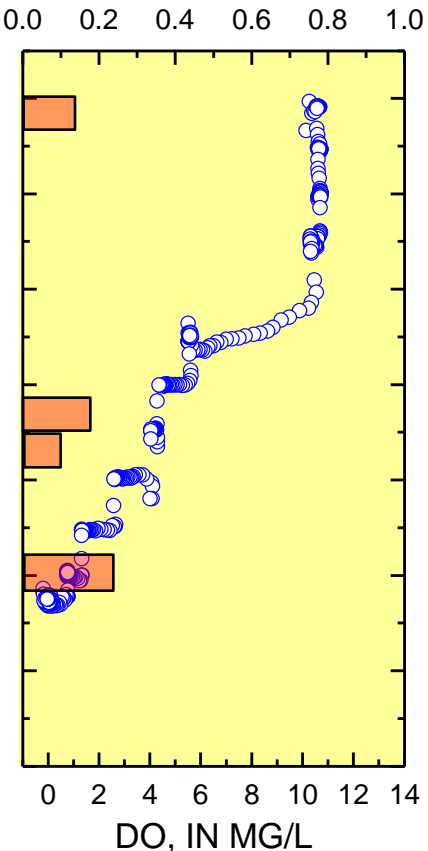
**NCR-3**

MEHg:THg (MASS)



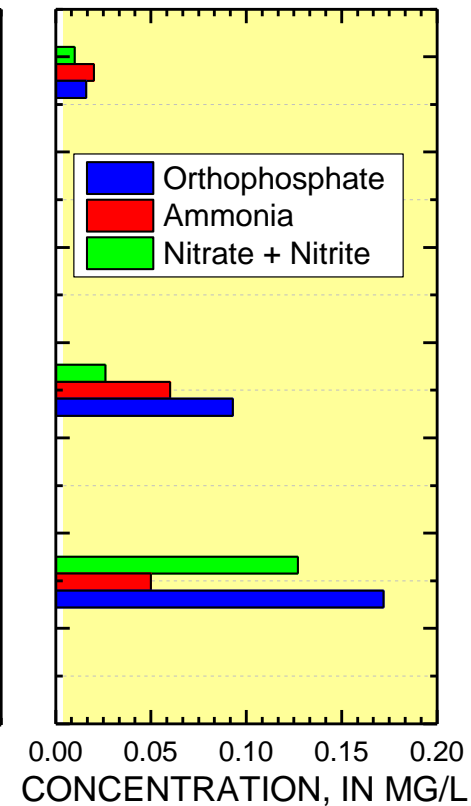
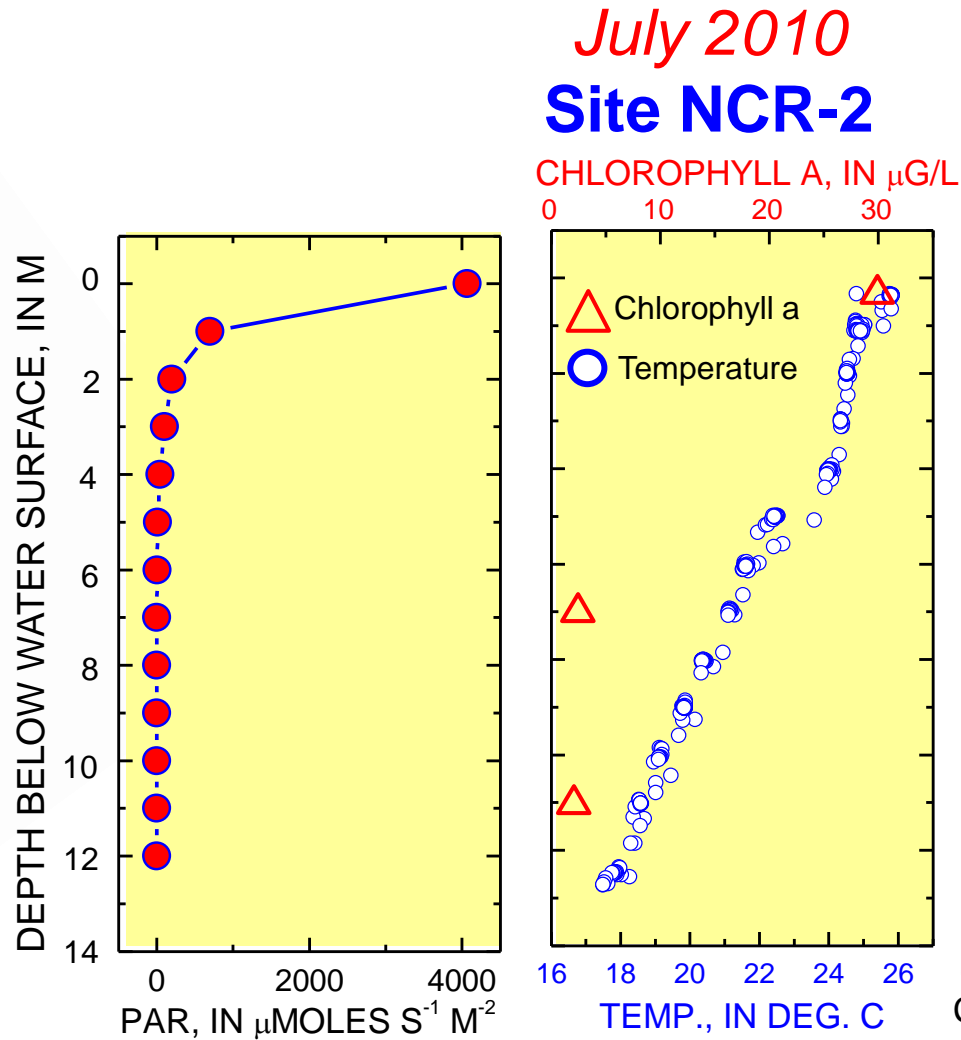
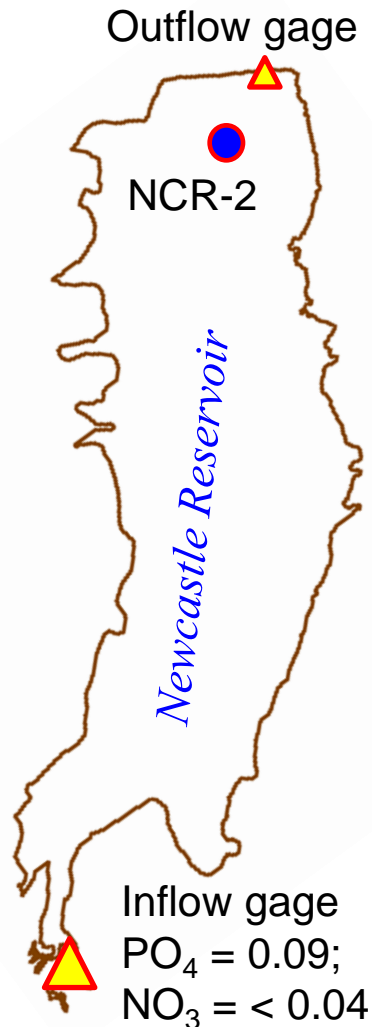
**NCR-4**

MEHg:THg (MASS)



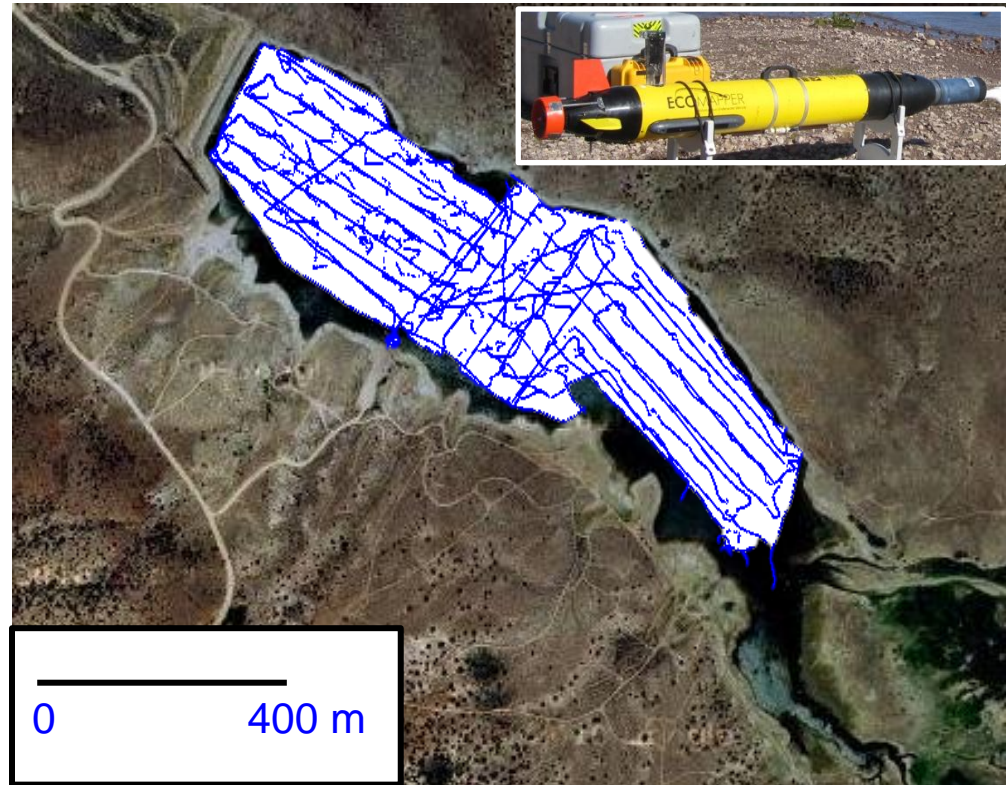


# NUTRIENT POOL AT DEPTH



## *Model Objectives*

- ◆ Simulate pumping of near bottom water to surface
- ◆ Simulate area of influence under different (1) pump rates; (2) pump positions; and (3) reservoir outflows

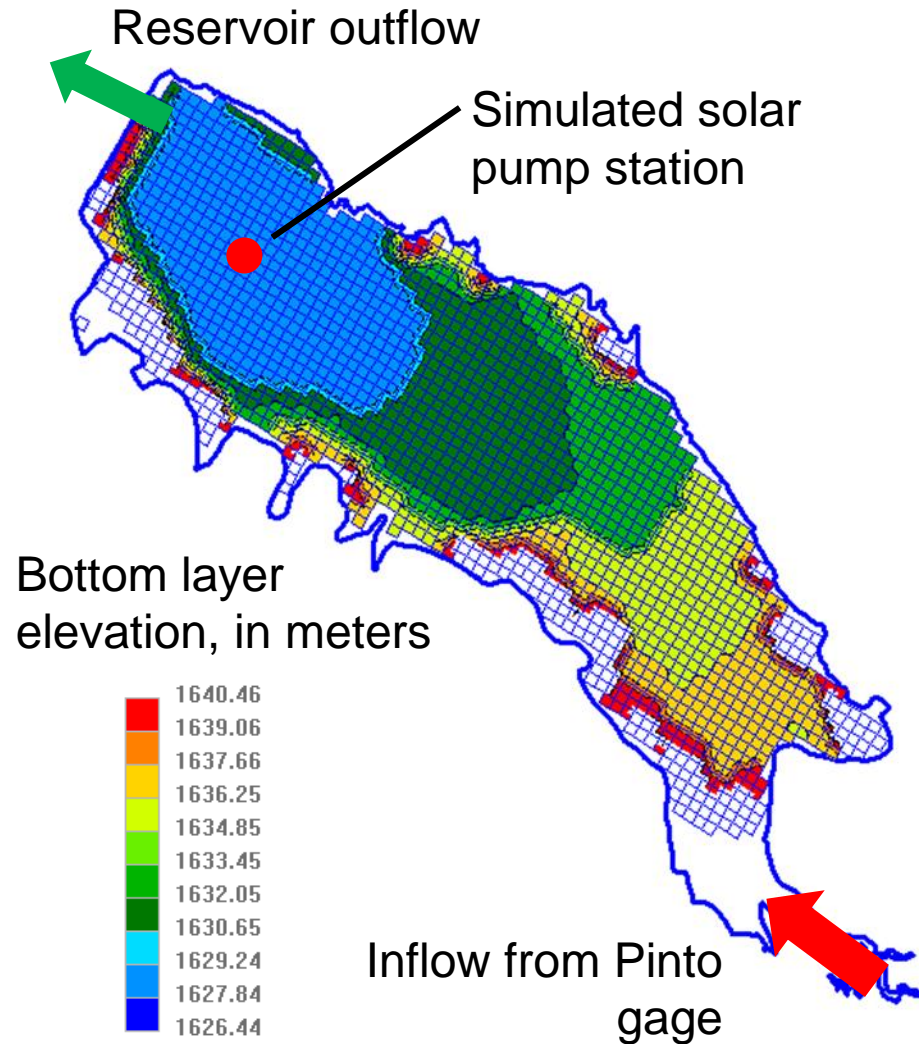


**Bathymetric survey lines from AUV (1 day)**

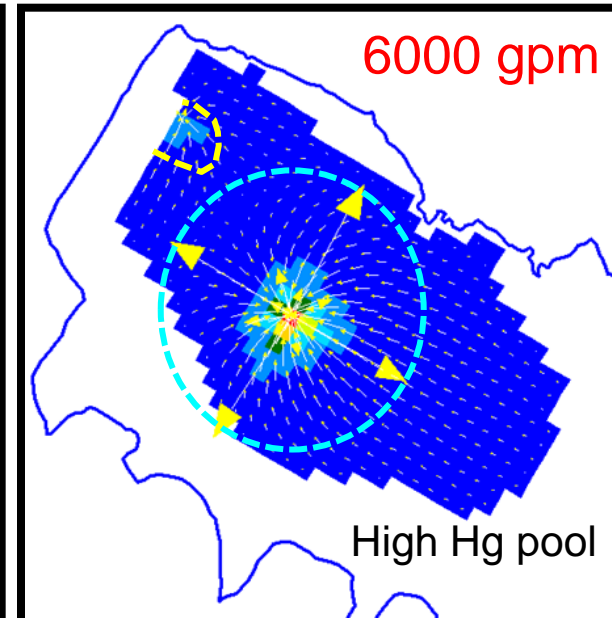
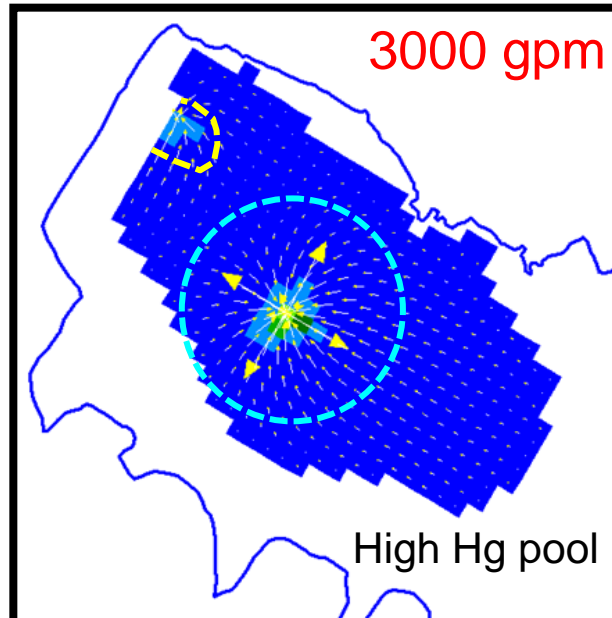
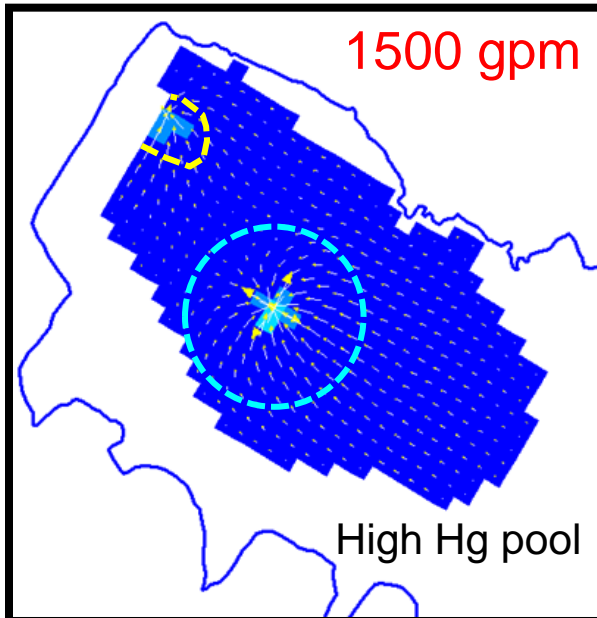


# BOUNDARY CONDITIONS

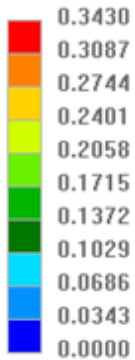
- ◆ 15-minute weather station data (Enterprise, Utah)
- ◆ Daily water-level data (regression model)
- ◆ Inflow from Pinto Creek gage (15-minute data)
- ◆ Hourly reservoir outflow data
- ◆ Pump locations and rates inserted at various model grid points



# PUMPING INFLUENCE



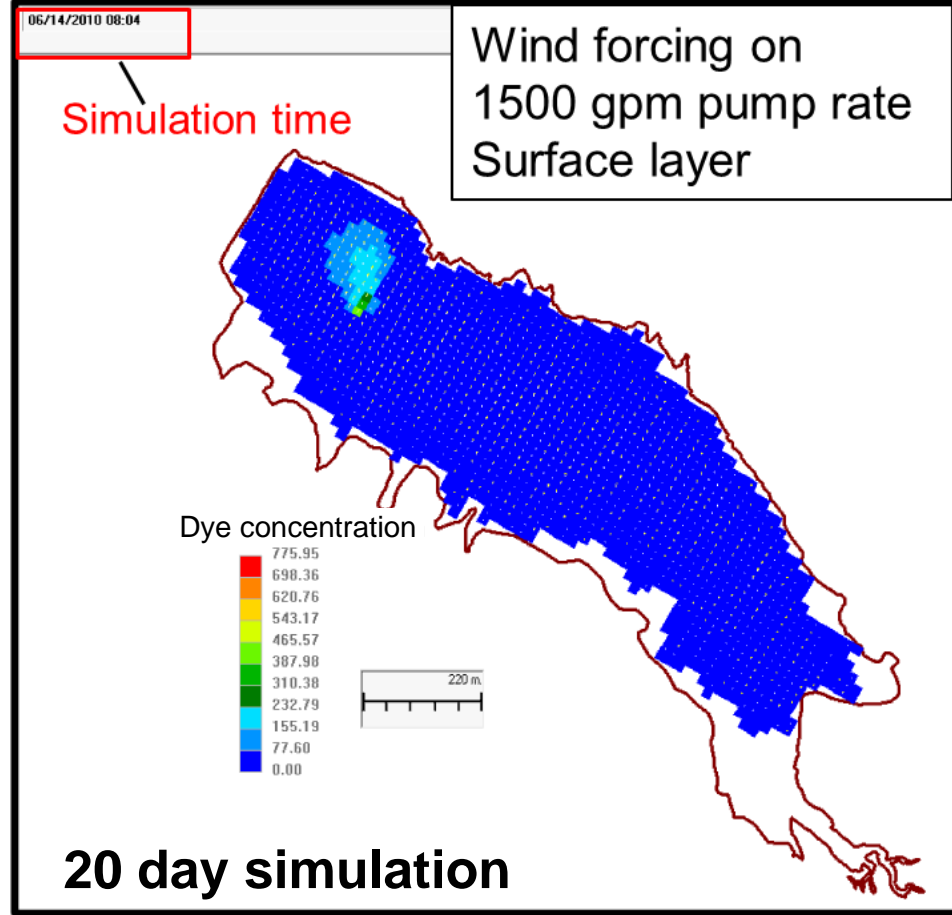
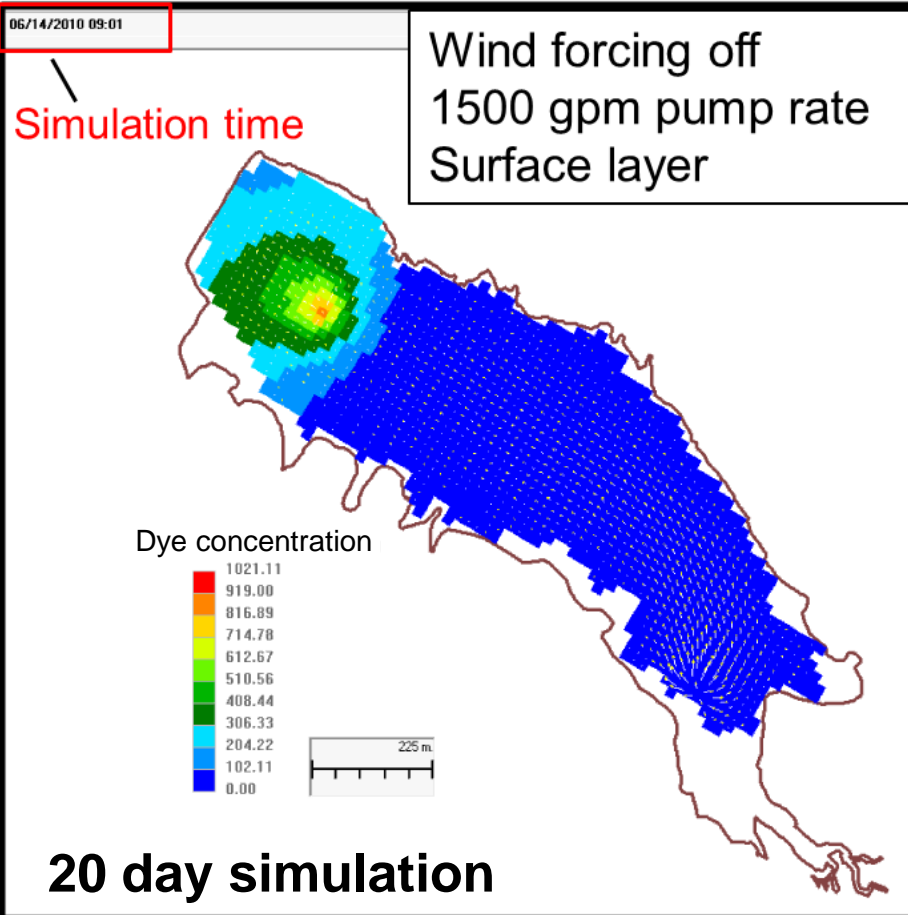
Velocity, cm/sec



- ◆ No wind, pump inlet in bottom layer, reservoir outlet at bottom, vertical pipe inflow and outflow
- ◆ Position pump to the NE and migrate up reservoir (take advantage of bottom water removal from reservoir outflow)?
- ◆ Position closer to reservoir outflow for Hg removal?

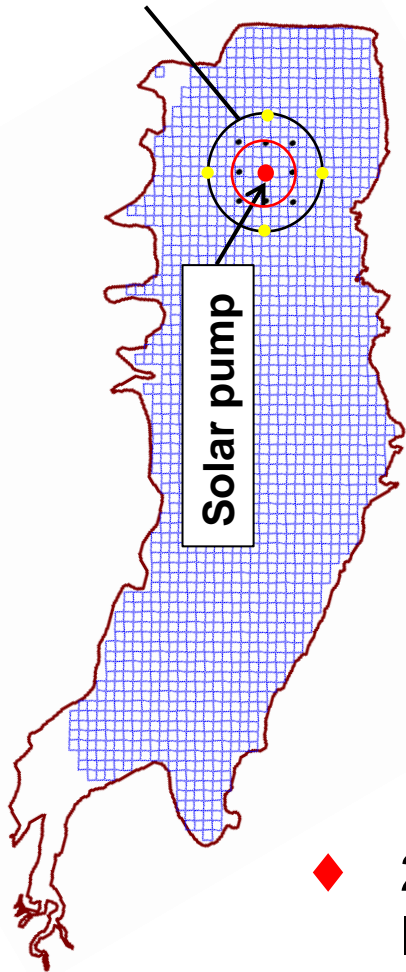


# NUTRIENT DISPERSION

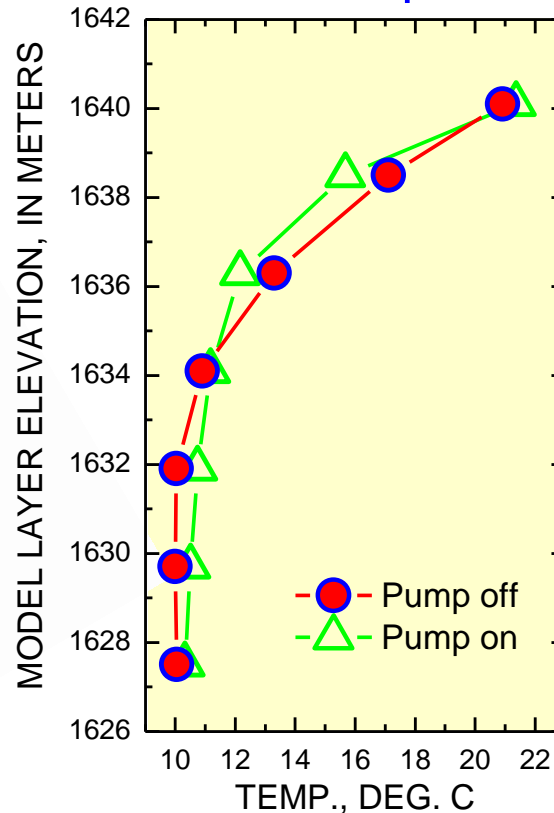


# THERMOCLINE IMPACTS

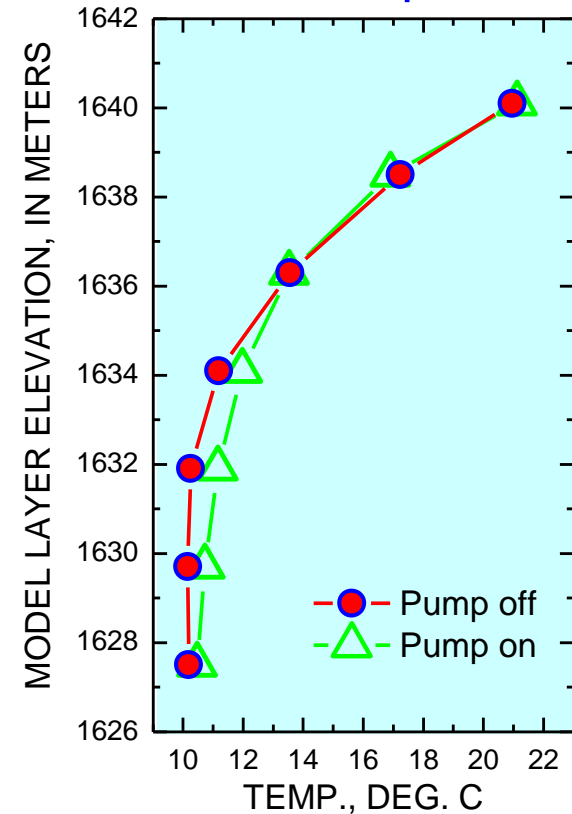
Profile “fences”



Inner profile



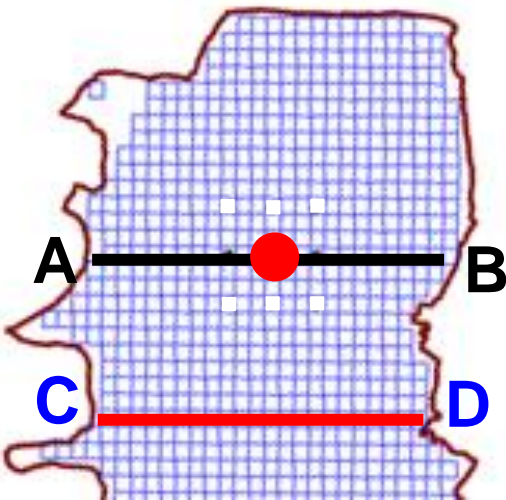
Outer profile



- ◆ 20-day pumping cools upper water column and warms lower water column relative to “pump off” simulation



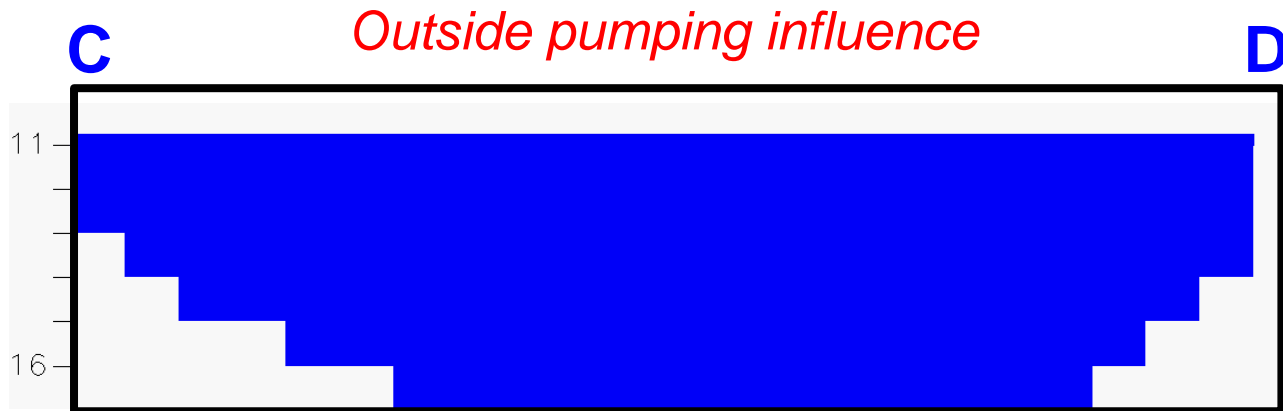
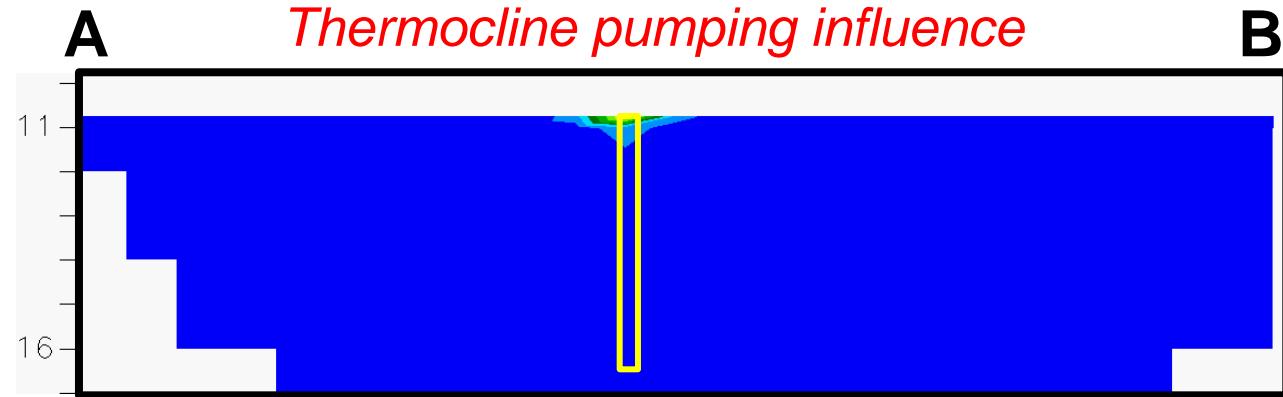
# THERMOCLINE IMPACTS



T in DEG. C

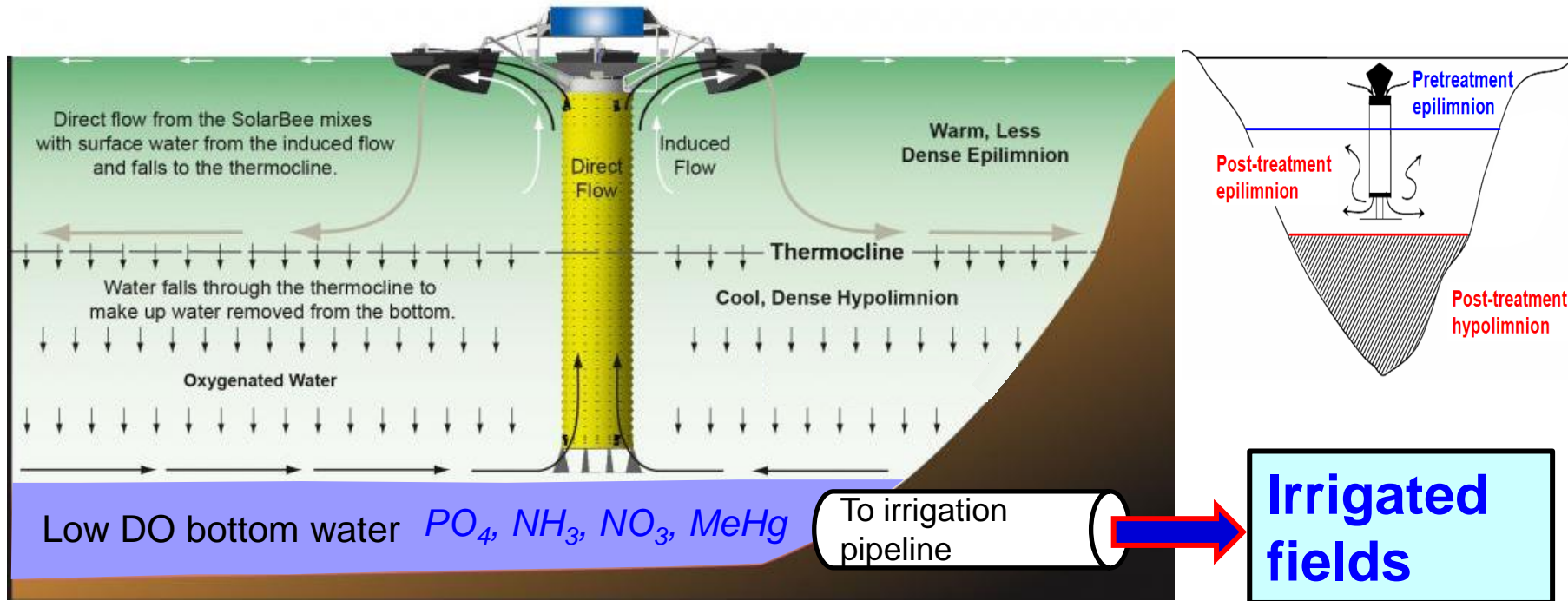


MODEL LAYER NUMBER



# Hg REMOVAL PROJECT

Modified from SolarBee, Inc.



- ◆ Solar-powered pump
- ◆ Reverse water flow (bottom → up)
- ◆ Oxygenate bottom water, photodegrade MeHg, export nutrients, and ??



April 2011 to July 2012

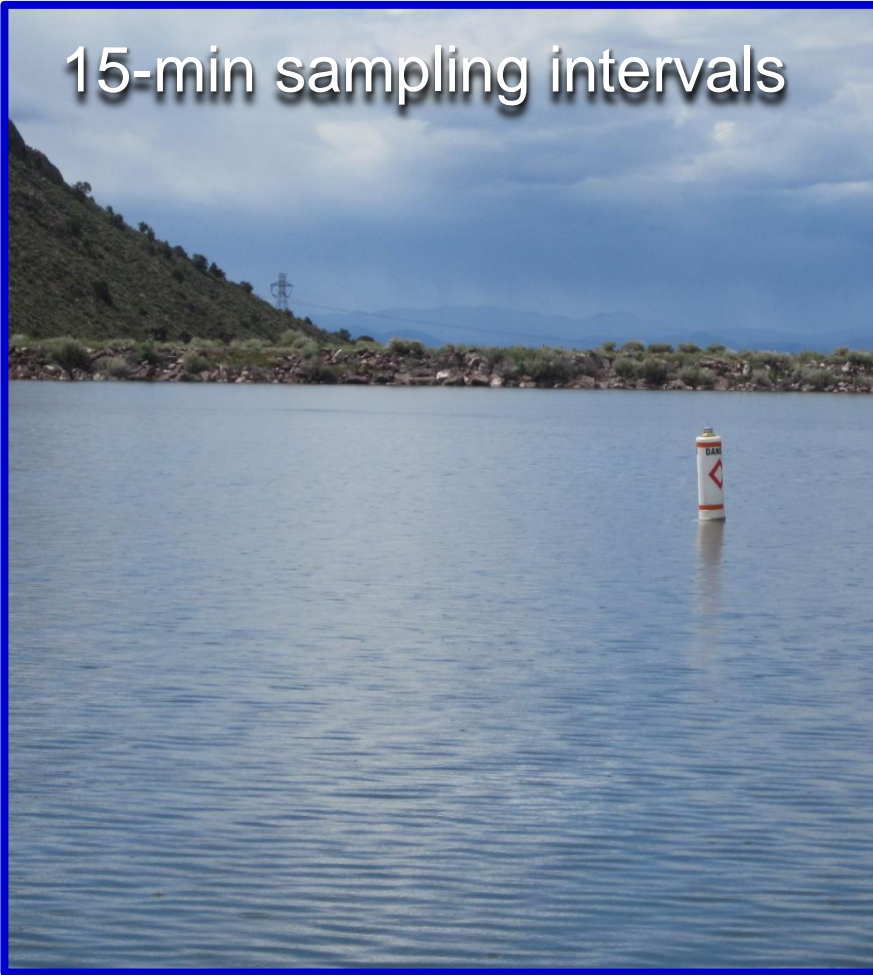


*Installation of solar pump on  
Newcastle Reservoir during July  
2011*

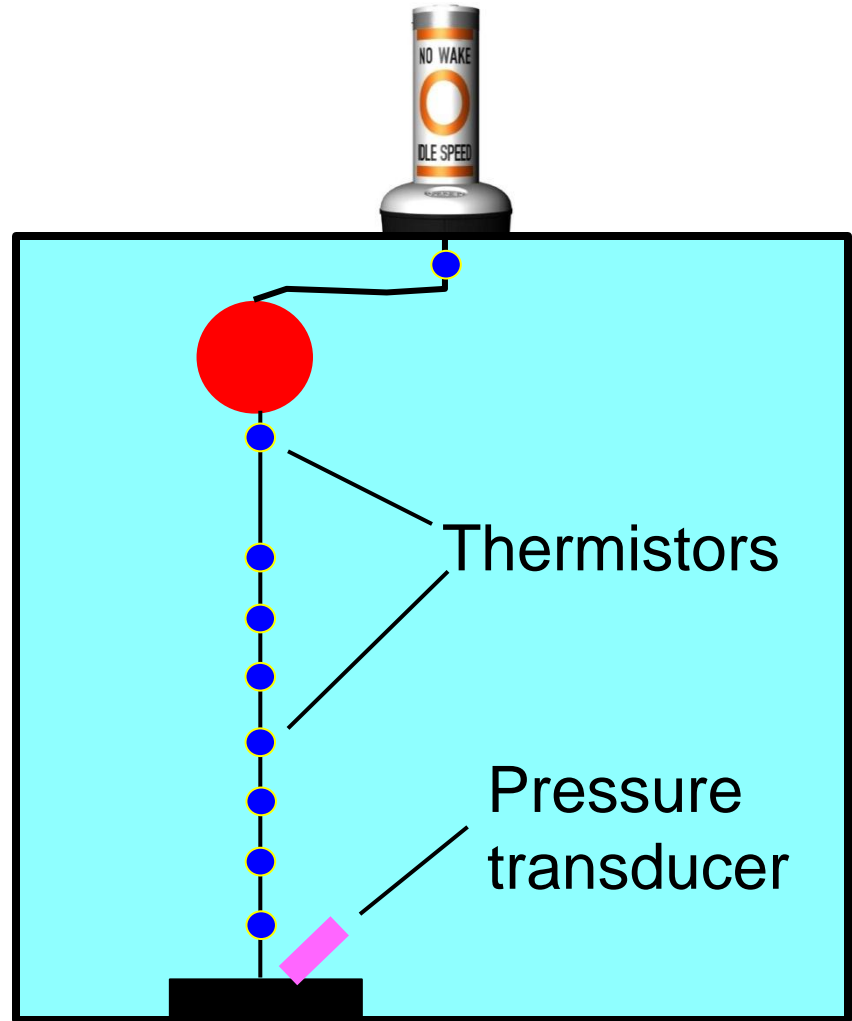
- ◆ Installed on-site weather station
- ◆ Installed thermal profiling station
- ◆ Collected pre-pumping tissue samples
- ◆ Solar pump deployed
- ◆ Post-installation QW and mercury monitoring

# THERMISTOR STRING

15-min sampling intervals



*Thermistor string, Newcastle Reservoir*





# SOLAR PUMP DEPLOYED

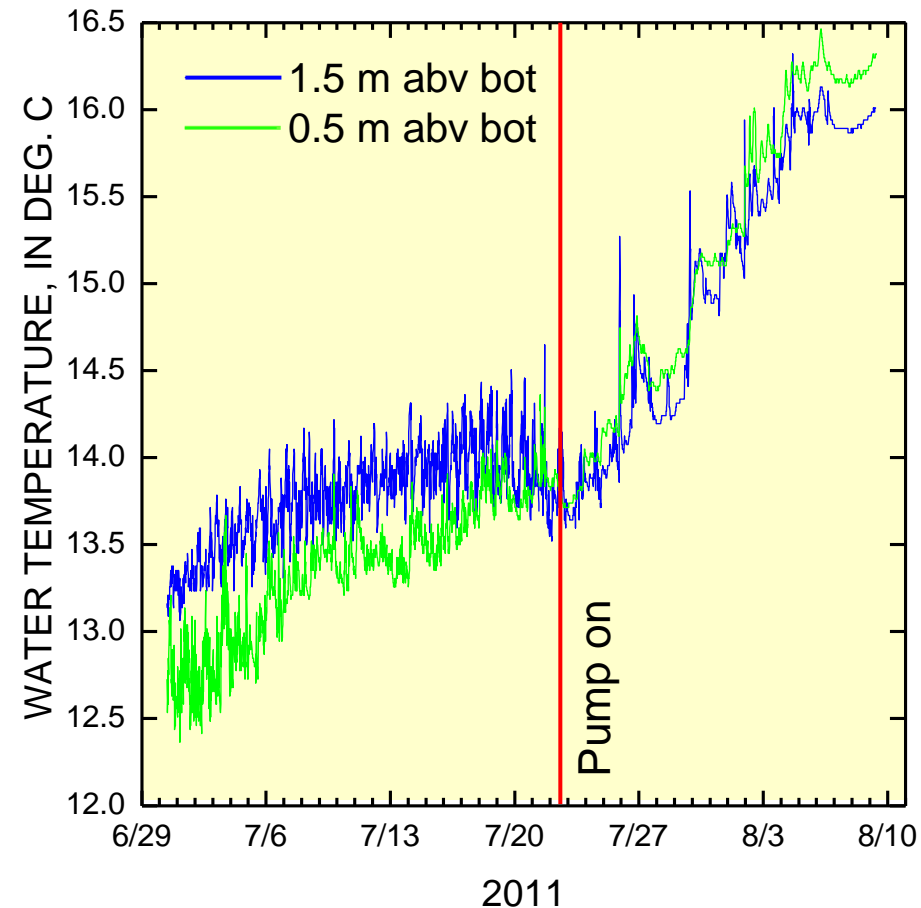
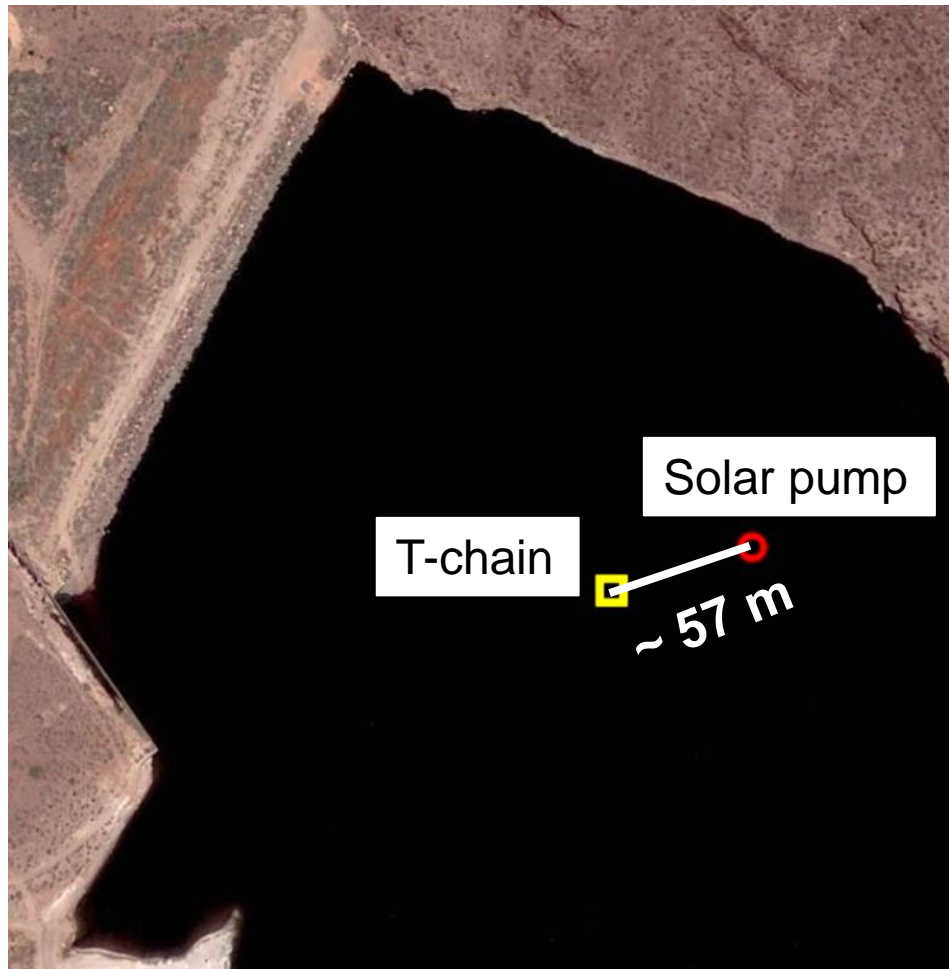


- ◆ 7,500 gpm total flow  
(1,500 gpm + 6,000  
gpm induced flow  
rate)
- ◆ 25-year life  
expectancy
- ◆ Operates 365  
days/year (through  
the ice-over season)

*Solar pump operating on Newcastle Reservoir  
during August 2011*

# POST-INSTALL TEMPERATURE

Temperature increase near bottom

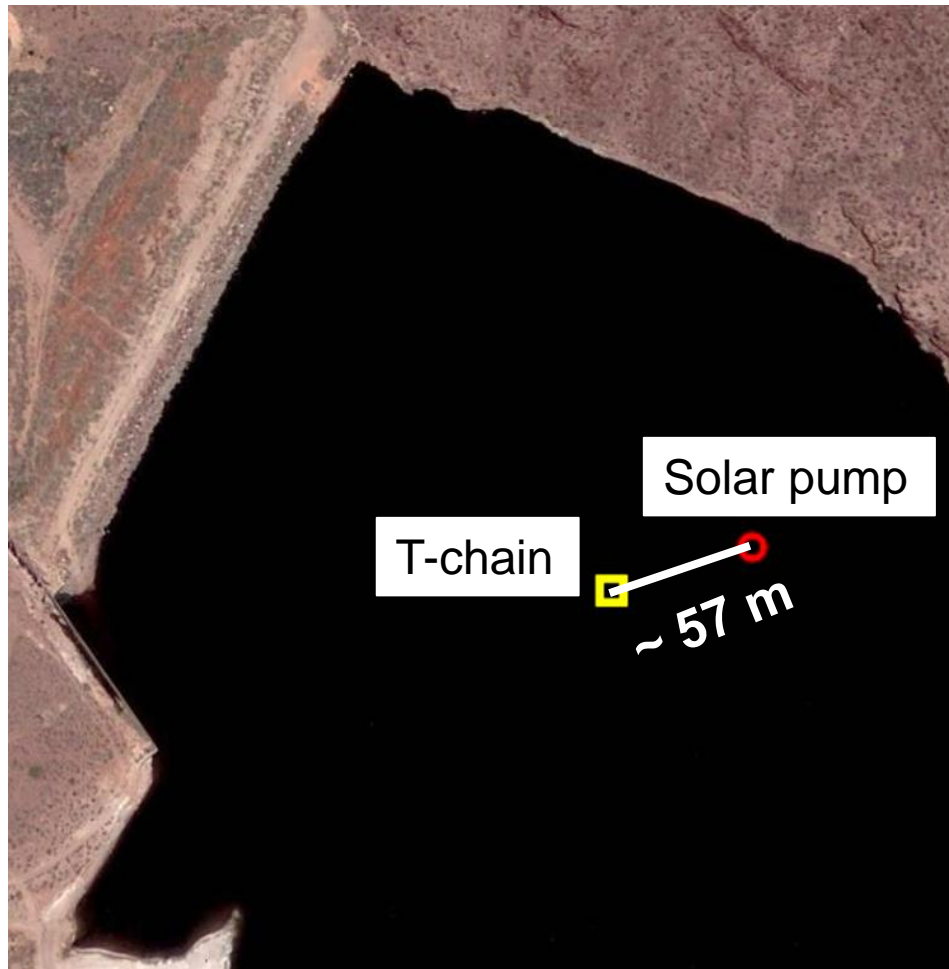


*Pump impacts thermal gradient*

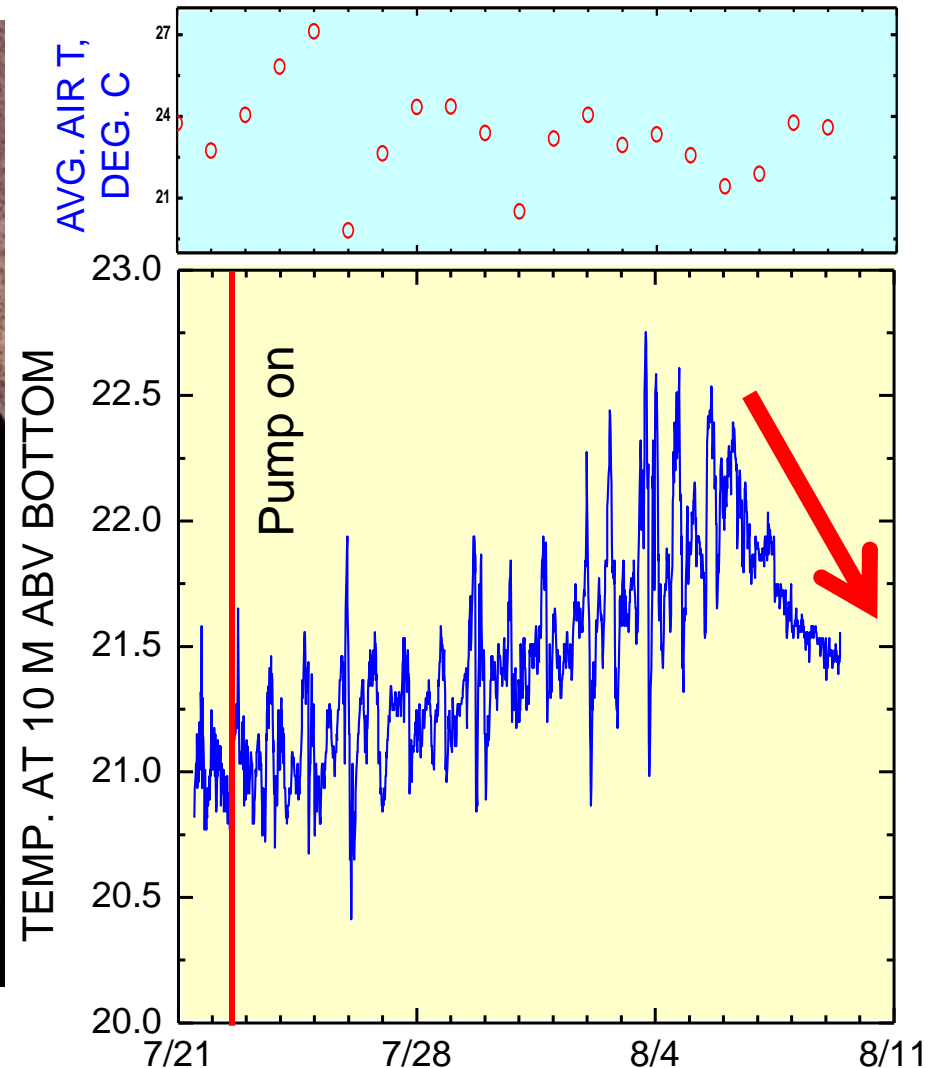


# POST-INSTALL TEMPERATURE

Temperature decrease near surface



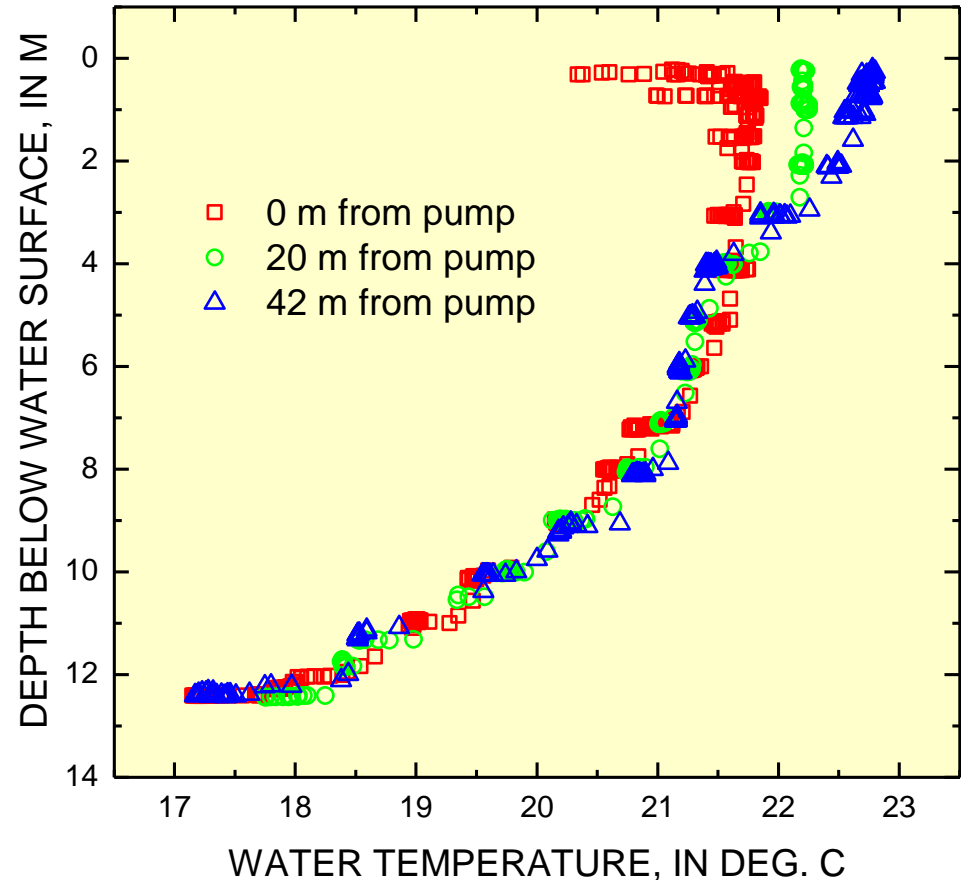
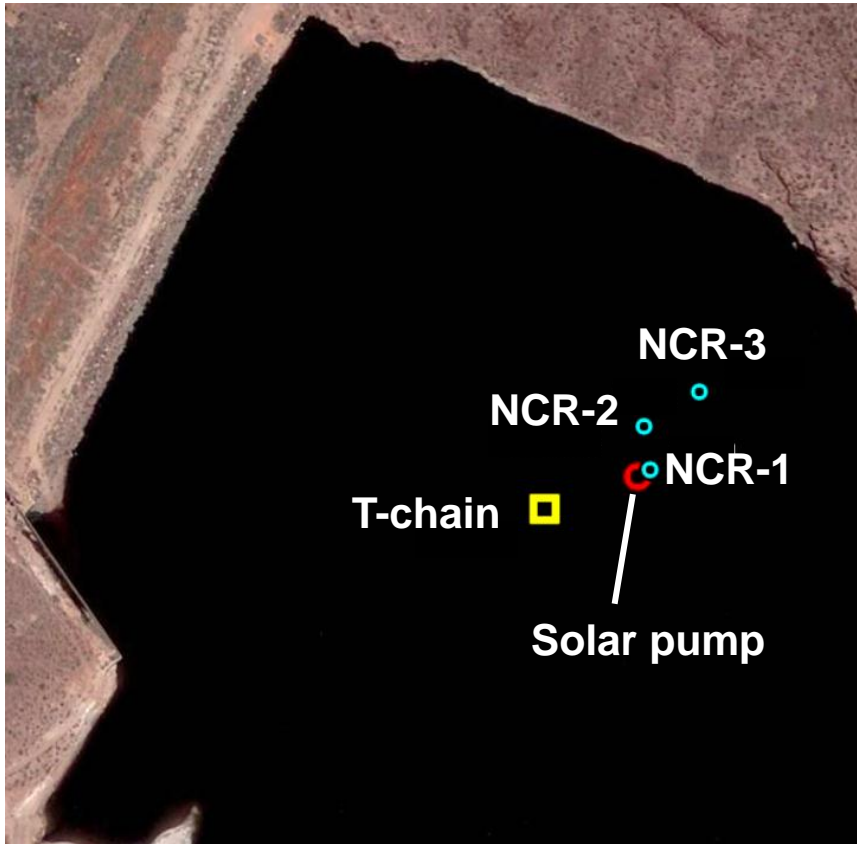
*Pump impacts thermal gradient*



... Pre-pumping ♦ Model results ♦ Remediation ♦ Watershed

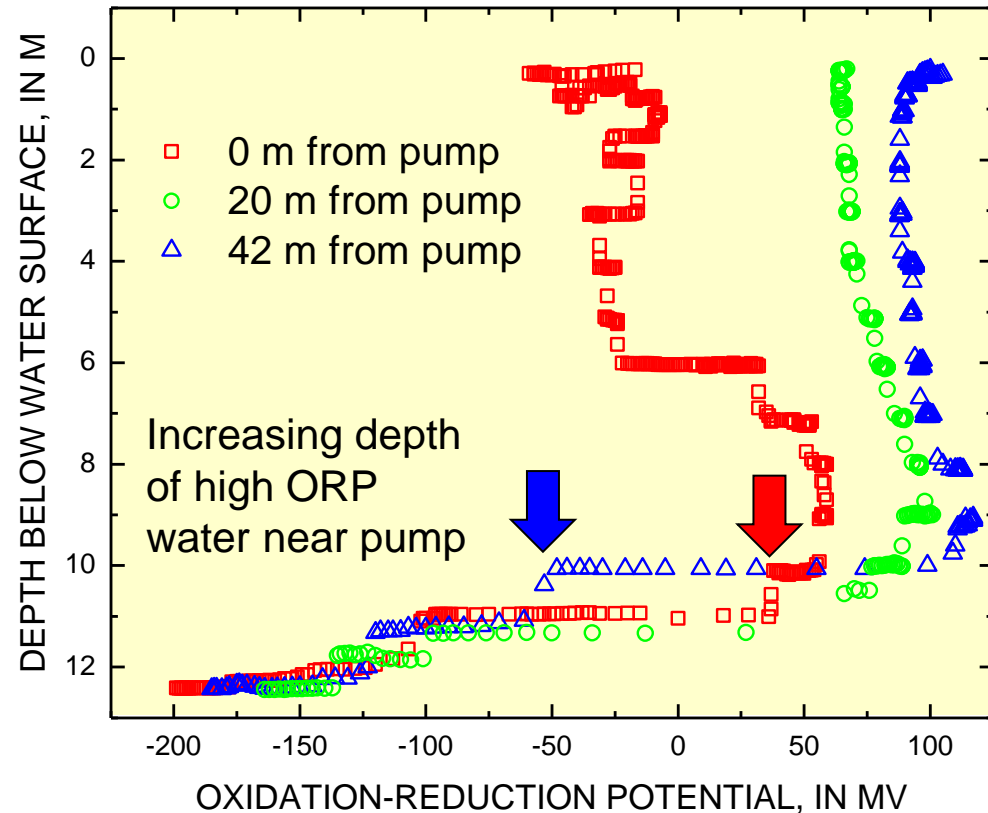
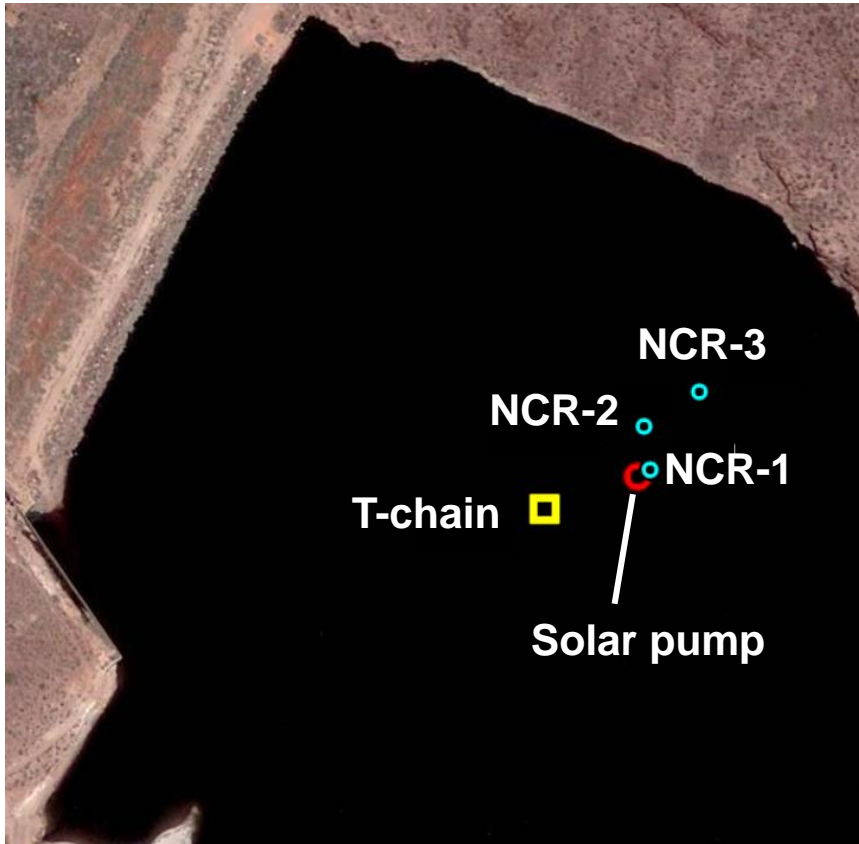
# POST-INSTALL TEMPERATURE

Temperature decrease near surface



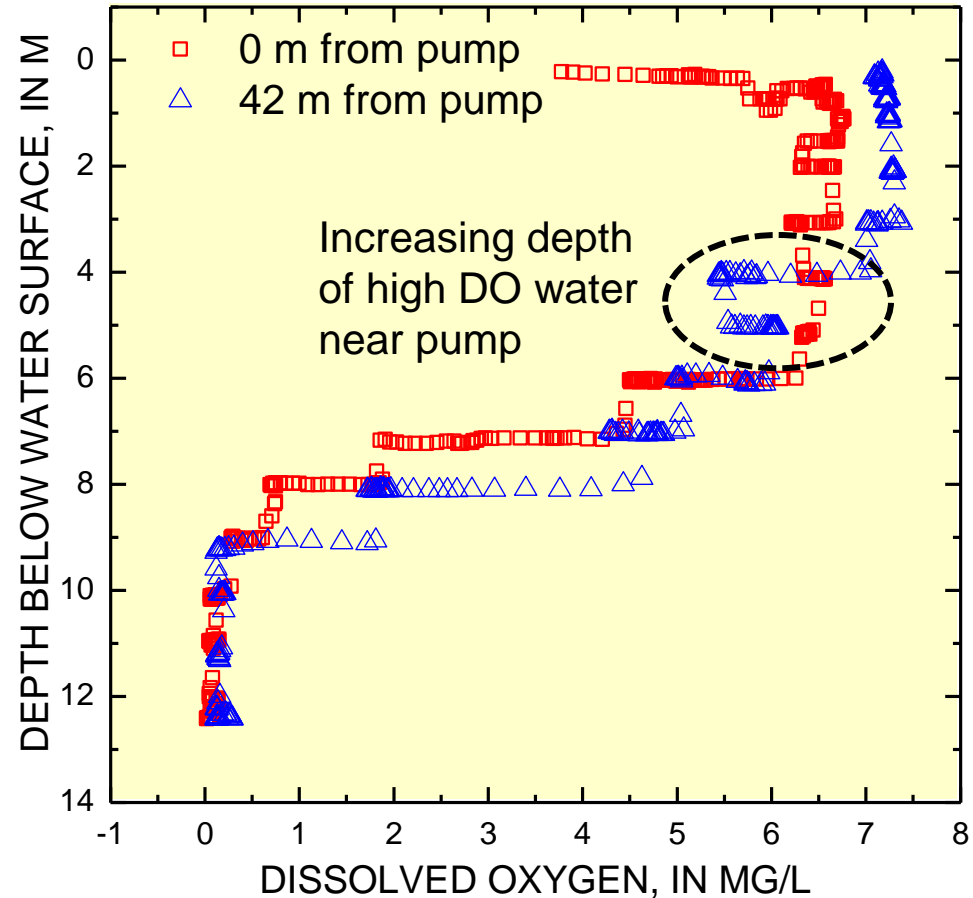
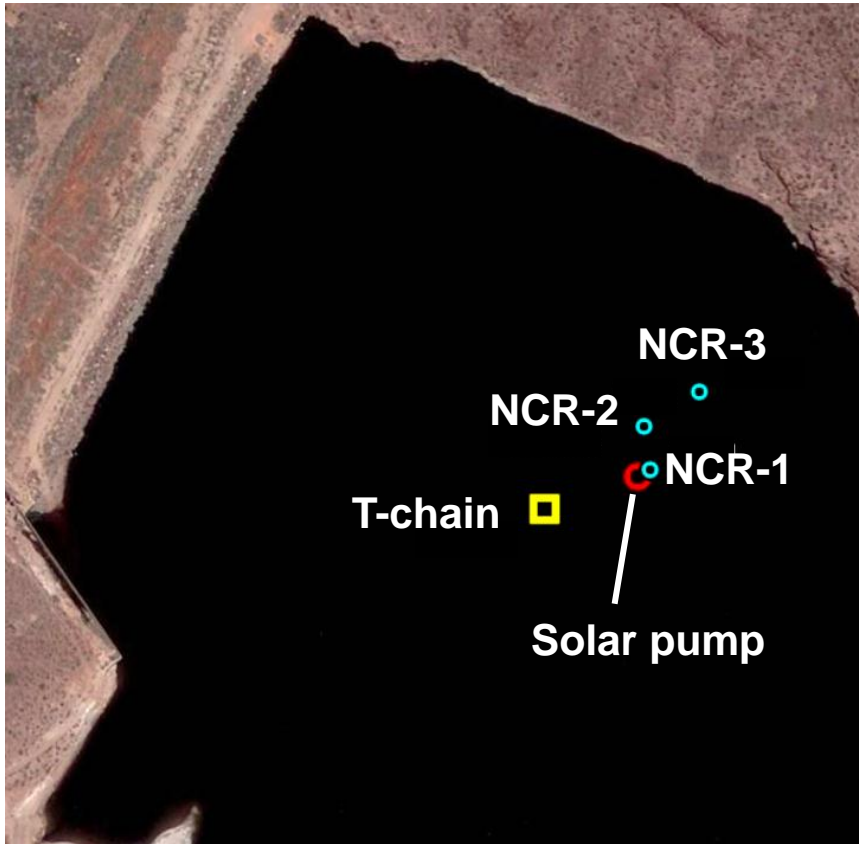


# POST-INSTALL PROFILE



- *Low redox water moving to surface*
- *Penetration of higher ORP water near pump*

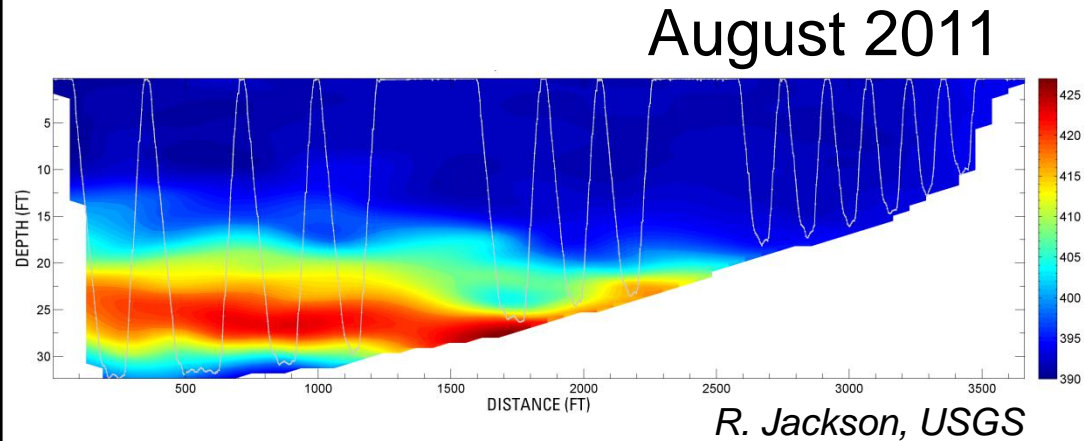
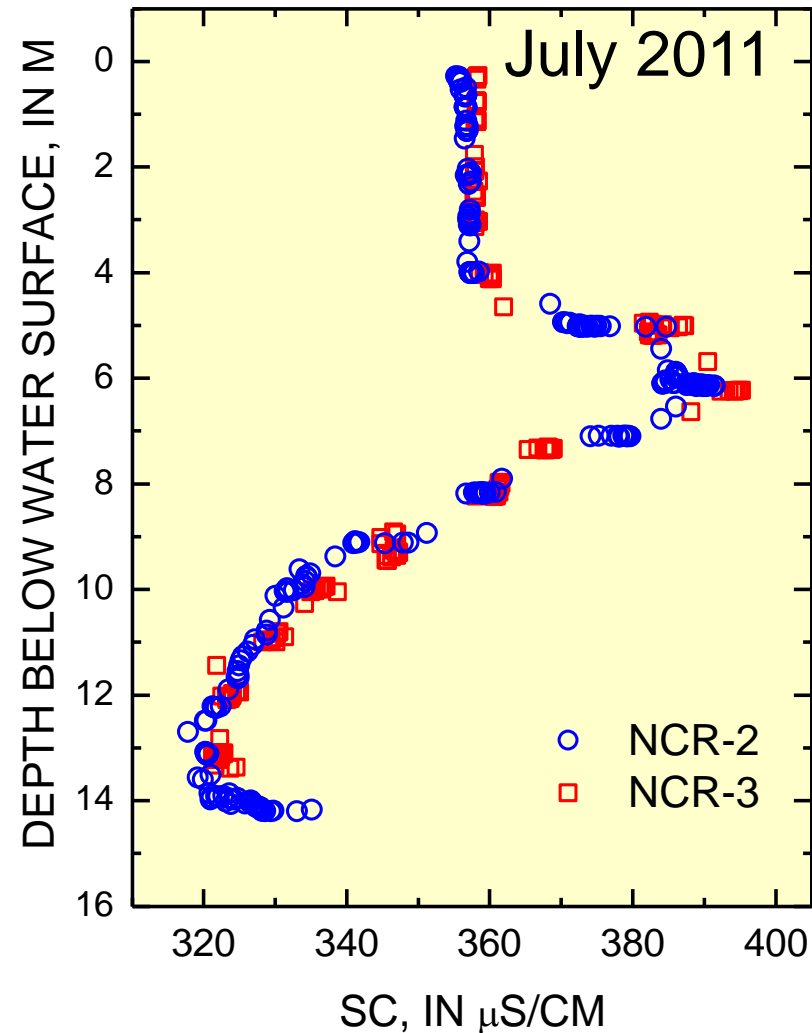
# POST-INSTALL PROFILE



- *Low DO water moving to surface*
- *Penetration of higher DO water near pump*

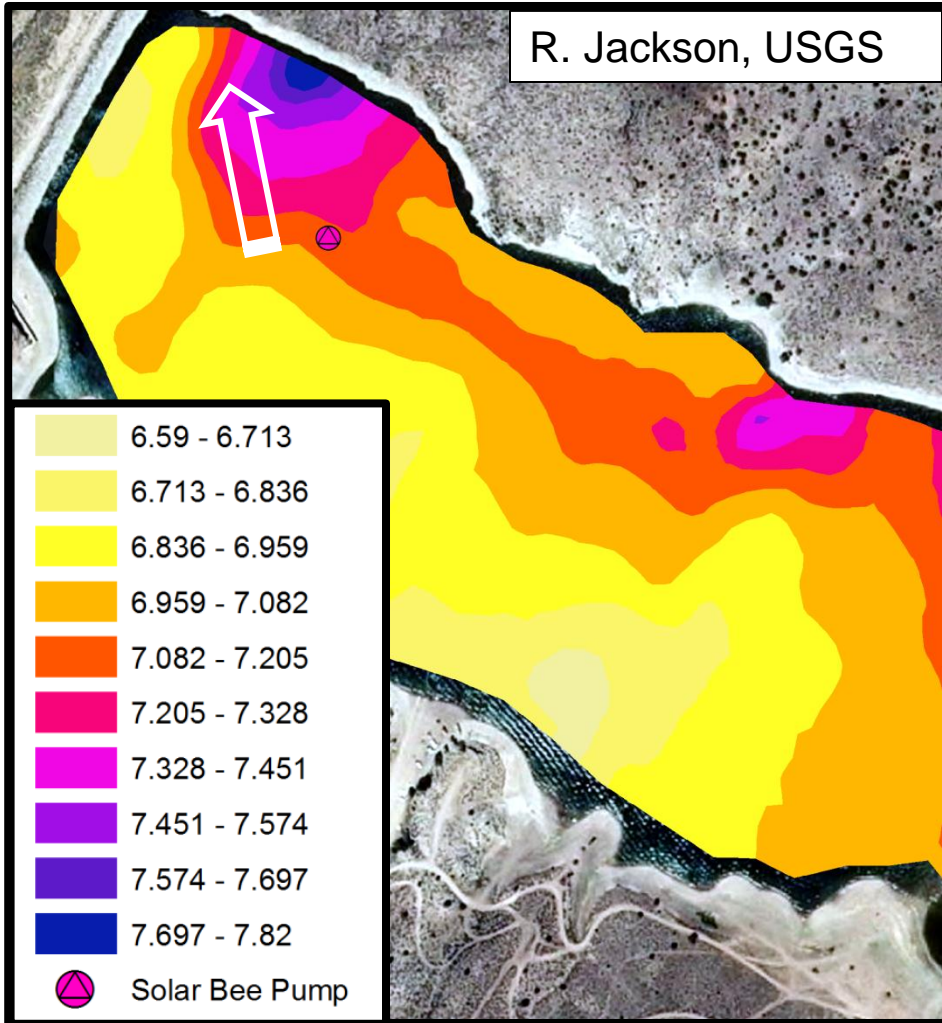


# SC X-SECTION

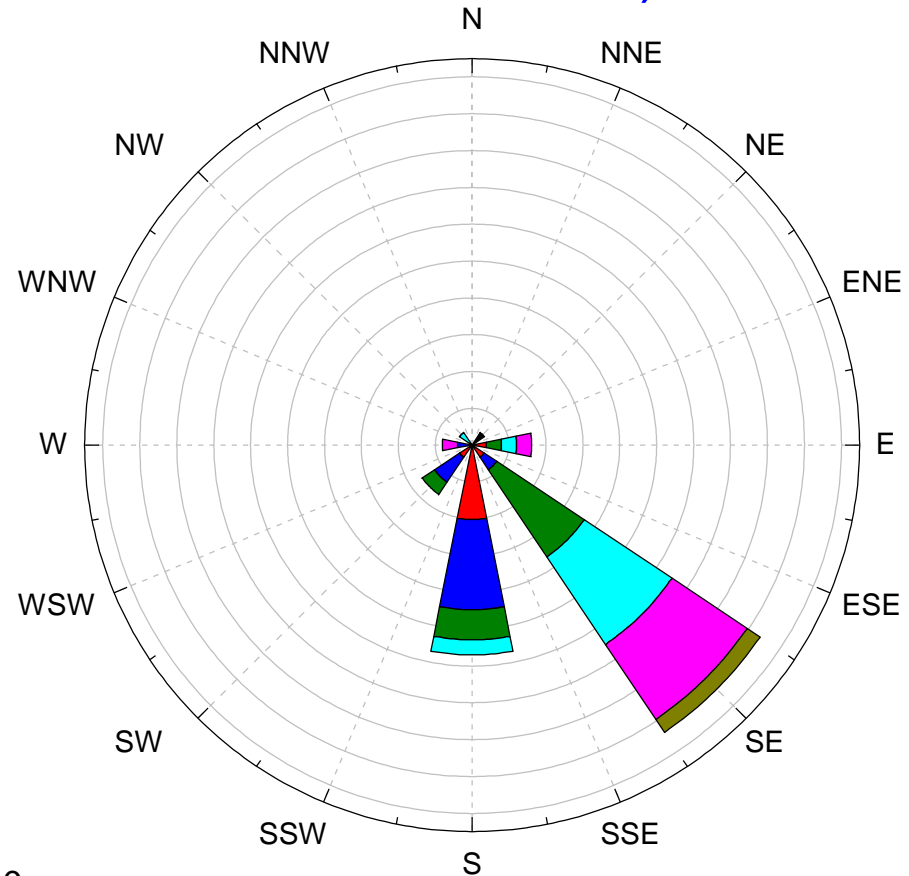


# POST-INSTALL AUV MAPPING

## Dissolved oxygen

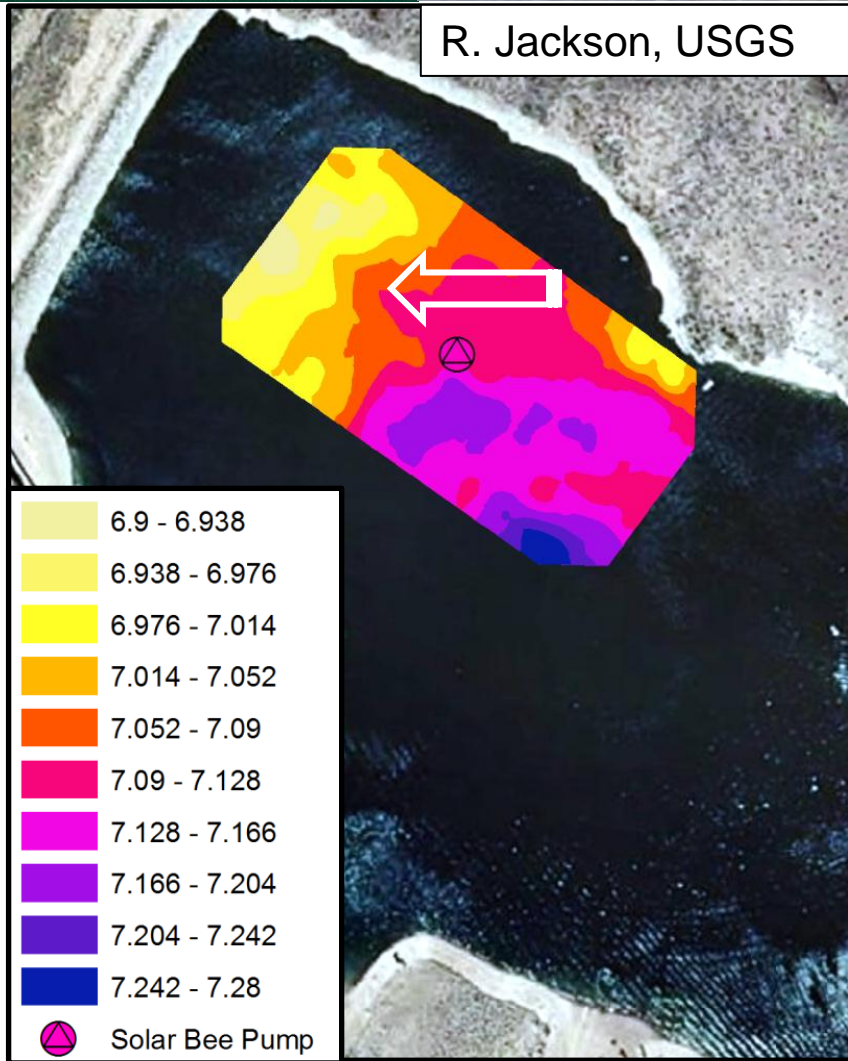


## Wind direction (August 8, 0900 to 1700 MDT)

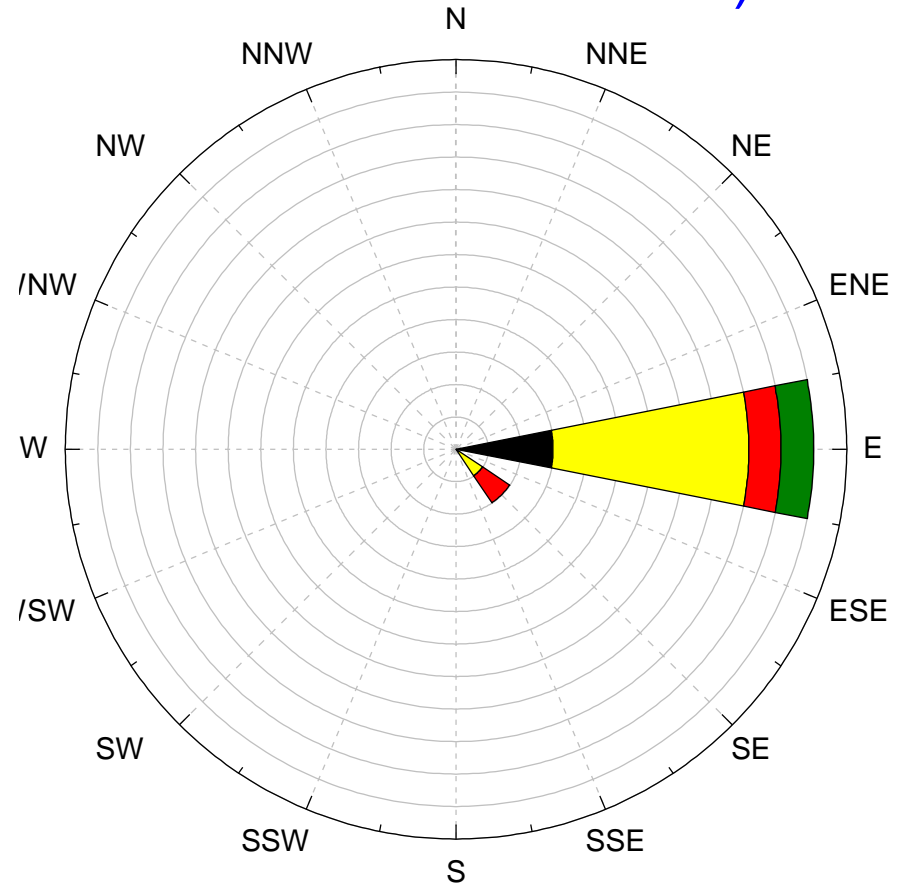


... Pre-pumping ♦ Model results ♦ Remediation ♦ Watershed





Wind direction (August 11,  
0730 to 0930 MDT)



## MERCURY CONCENTRATIONS IN FOREST TREES FROM SLOVAKIA

BLANKA MAŇKOVSKÁ

*Forest Research Institute, Masarykova 2195, 961 92 Zvolen, Slovakia*

Particularly high values of Hg were found in the soil of A zone in the vicinity of the iron ore mines in Rudňany. These values are 1800 times the values found by Jonasson and Boyle (1979) in uncontaminated soil. Statistically significant

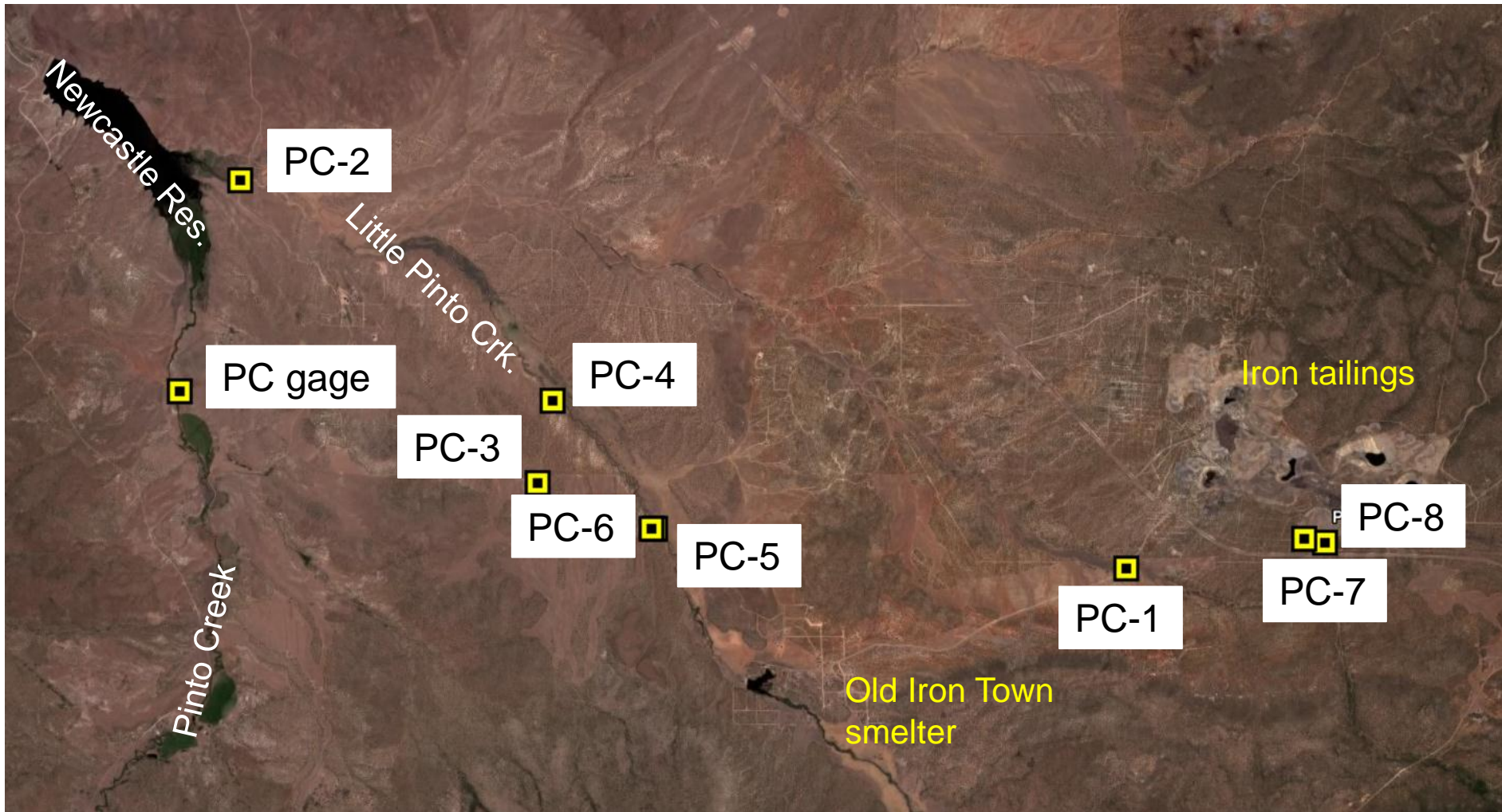
*Water, Air, and Soil Pollution* **89**: 267–275, 1996.

© 1996 Kluwer Academic Publishers. Printed in the Netherlands.

- ◆ Channel sediment sampling (-200 mesh)
- ◆ Analysis for total Hg
- ◆ Little Pinto Creek watershed



# WATERSHED Hg INPUTS?



... Pre-pumping ♦ Model results ♦ Remediation ♦ Watershed



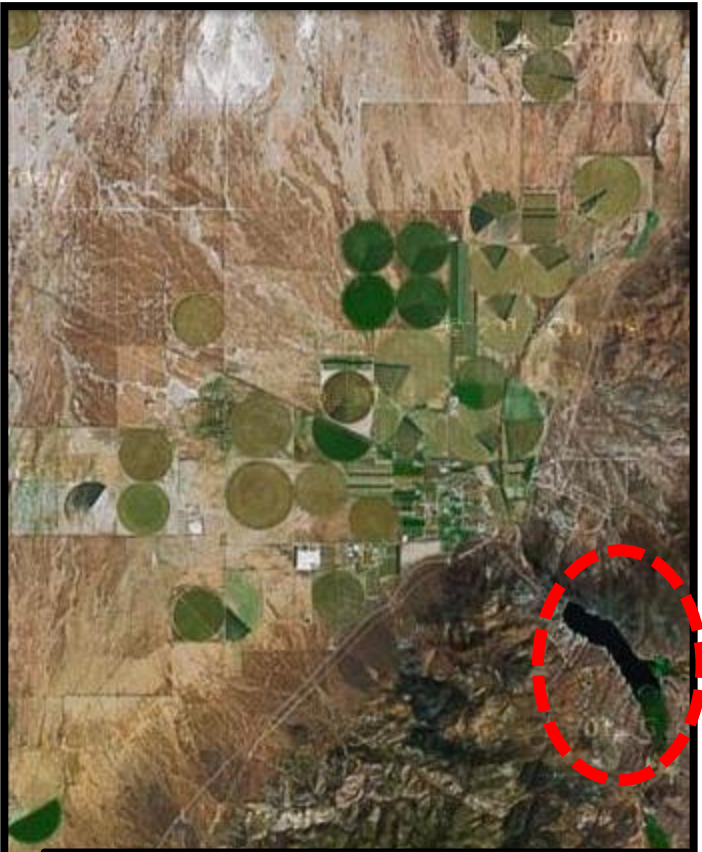
# Hg IN IRRIGATED FIELDS

Biological detection and analysis of mercury toxicity to alfalfa (*Medicago sativa*) plants

Zhao Sheng Zhou, Shao Jing Wang, Zhi Min Yang \*

Chemosphere 70 (2008) 1500–1509

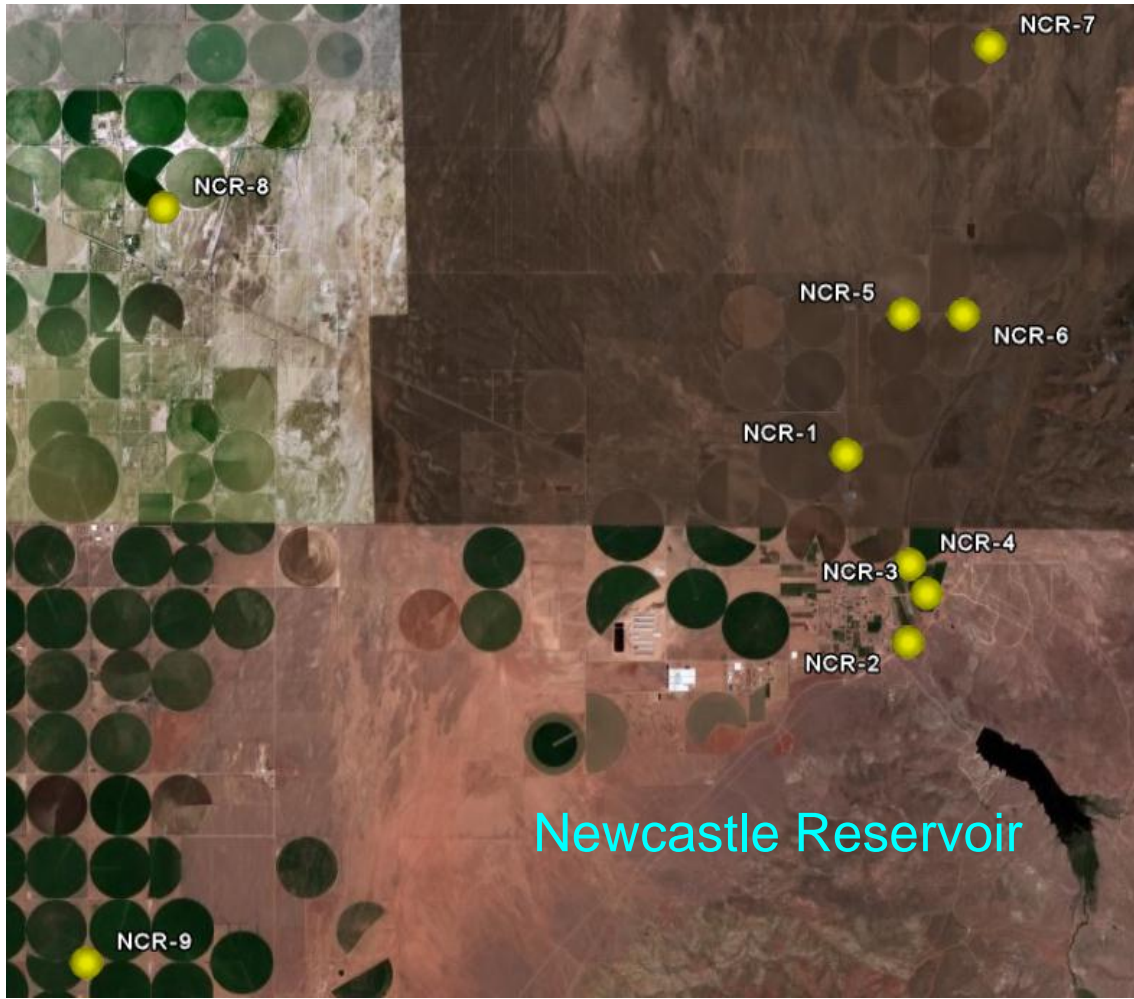
Due to anthropogenic activities such as mining, smelting, and application of fertilizer, sewage sludge, and Hg-containing fungicides to soils, the annual import of toxic mercury into the agricultural lands and other ecosystems has become an increasingly important concern (Patra and Sharma, 2000). It has been estimated that, in 2000, the average Hg level in global arable lands was  $39 \text{ kg km}^{-2}$  (Han et al., 2002). The large input of mercury into the arable lands has resulted in the widespread occurrence of mercury-contamination in the entire food chain. Mercury is a unique metal due to its different forms (e.g. HgS,



Newcastle Reservoir



# Hg IN IRRIGATED FIELDS



- ◆ Soil and plant samples collected from irrigated fields (pre-pumping)
- ◆ Groundwater vs. reservoir water
- ◆ Samples being analyzed for Hg
- ◆ Repeat soil and plant samples will be collected in 2012 (post-install)



# SUMMARY

## ATTENTION ANGLERS

### FISH CONSUMPTION ADVISORY

High levels of mercury have been found in Wiper

*Where:* Newcastle Reservoir

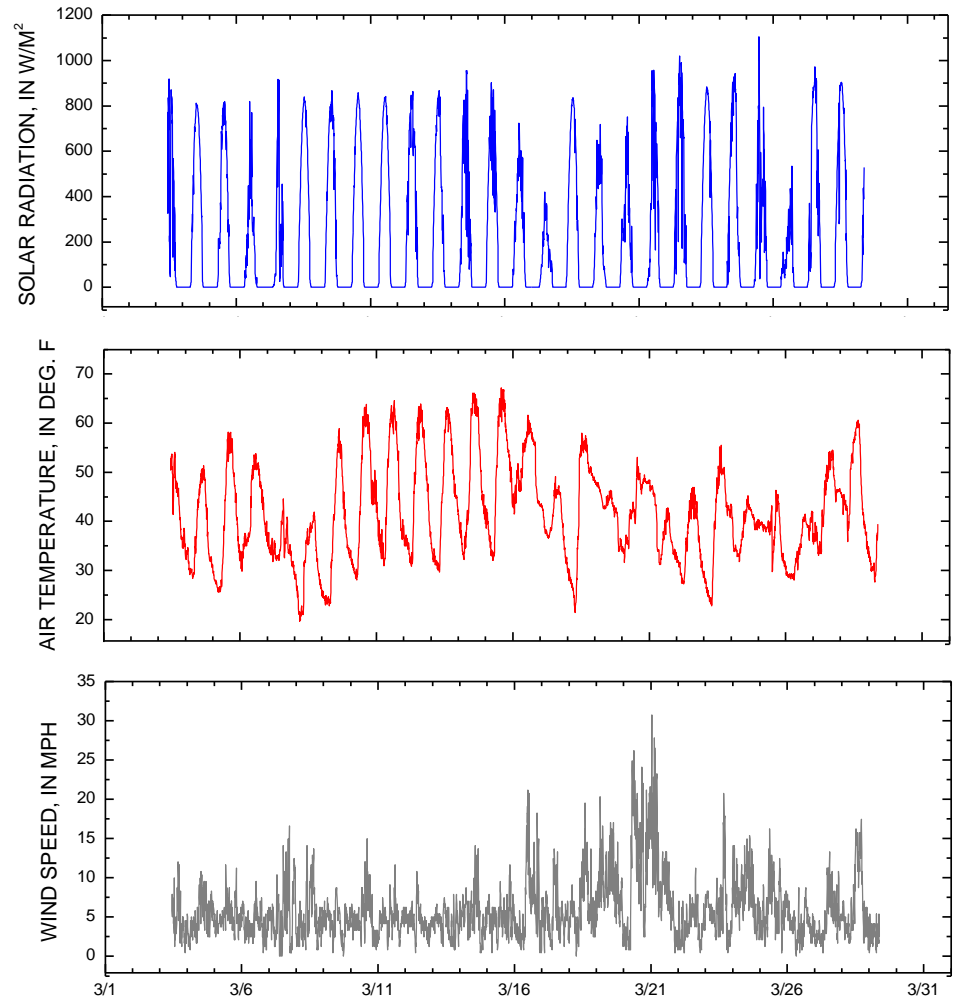
#### *Recommendation:*

- Utah public health officials recommend that adults NOT eat these fish.
- Pregnant women, nursing mothers, and children under 12 are also advised NO to eat these fish.





*Newcastle Reservoir weather station*



2011

## Fishing Utah Brett Prettyman



Brett Prettyman writes about the outdoors, recreation and fishing for The Salt Lake Tribune

### Article Tools



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Published 4 hours ago 0 Comments  
» **Minersville Report - 6-pound trout**

### *Newcastle Survey — Wipers and rainbows*



Published on Apr 4, 2011 09:16AM 0 Comments

Newcastle Gillnetting Survey — Lots of healthy-looking wipers up to 3 lbs caught during the gillnet survey at Newcastle Res. on March 30. Also good numbers of rainbows of two size classes: 12-14 inches and 17-18 inches. We saw more of the larger size than we have in recent years. Wipers are really helping the trout by reducing the number of golden shiners. Fishing is fair to good for rainbows right now. Tougher fishing for wipers but success should pick with warming water temps.

- ◆ 30 fish collected at Newcastle and Enterprise (control) reservoirs
- ◆ Submitted to USGS Hg Research Laboratory for Hg<sub>(total)</sub> analyses
- ◆ Sample splits for Hg laboratory round robin with USEPA